KNOWLEDGE

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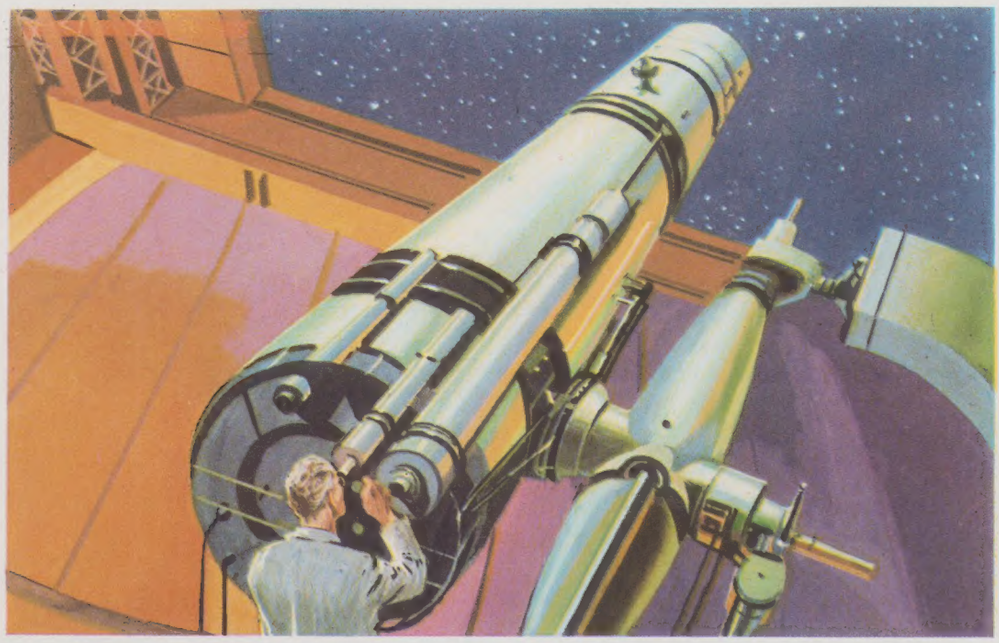
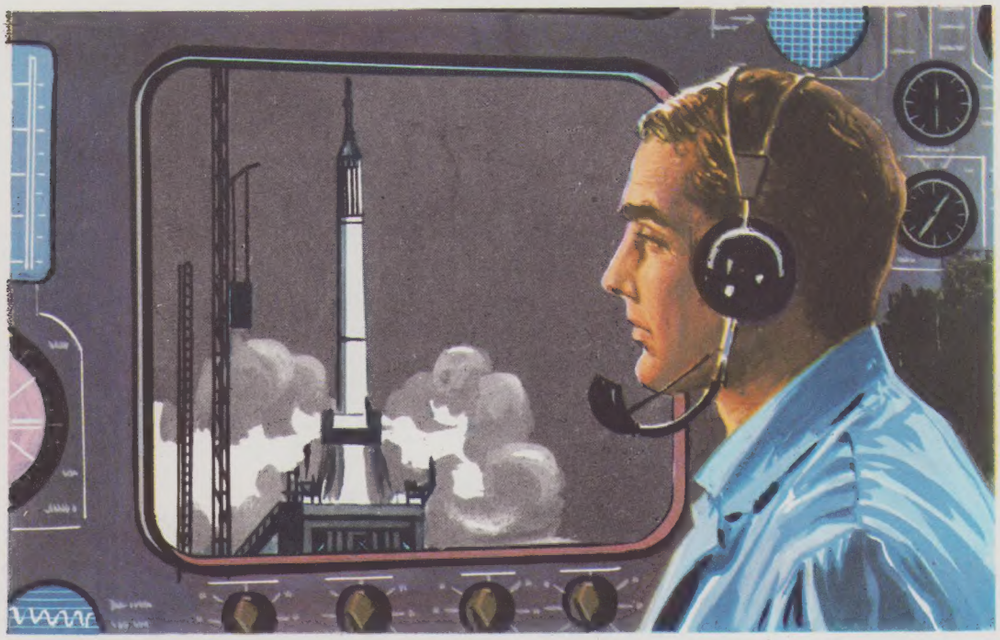
S SCIENCE (part one)



An astronomer, using a powerful telescope. This helps him to observe the celestial bodies, to study their changing positions, movements, and physical characteristics



A technician, applying the laws discovered by the astronomers, directs the launching of an artificial satellite, controlling it by means of the television screen of a complicated apparatus

Previous page: Science explains the laws that govern natural phenomena. The formula on the cover was discovered by Albert Einstein and expresses the conversion of matter into energy, or vice-versa.

IF one of our early ancestors were to return for a visit to our present world, he would be greatly amazed by the sight of so many marvellous inventions.

Seeing the roaring monsters which rush across land, sea, and sky, he would think that he had come to a world of magicians. The only means of transport he knew was the four legs of a domestic animal. As to the great structures – skyscrapers, dams, bridges, roads – they would seem to him superhuman. He would be astonished at the many buildings in which men work – factories, hospitals, laboratories, warehouses, offices – all displaying a never-ending spectacle of efficient organisation. When he recovered from his first bewilderment, he would realise that his descendants had made enormous strides in all directions. What he would have seen is the direct outcome of *Technology*.

Science and technology

In science, men try to discover laws of nature. In Technology (or Applied Science) they use these laws to invent instruments to make their lives easier, safer, and more comfortable.

In *Pure Science* we analyse observations about the world and try to put them into some sort of system. The aim is to satisfy a basic need of human intelligence: to discover the laws that govern natural phenomena. Scientists, over the centuries, have carried out more and more experiments and have developed increasingly precise and efficient tools for investigation, thus learning more and more about the world. Let us take the science of *Astronomy* as an example, and consider some of the main views held over the centuries.

Early theories in astronomy

Astronomy first arose along with astrology, the art by which men tried to foretell the future through observing the stars. The observations gave man considerable knowledge of the Universe. At first it was believed that the Earth lay at its centre, with the Sun and the planets revolving round

KNOWLEDGE NEWS

Week beginning 19th May 1963

THIS WEEK'S SPECIAL ISSUE OF 'ANIMALS' HAS

40 PAGES!

★ ★ ★

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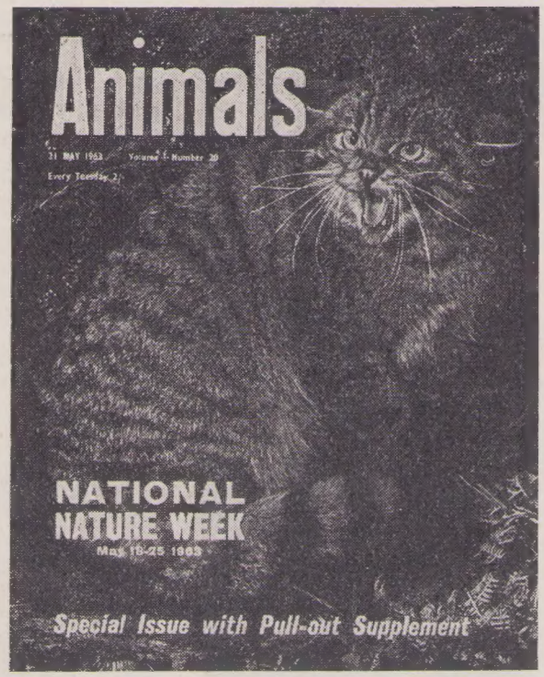


★ ★ ★

TO mark Britain's first Nature Week, this week's issue of 'Animals' is a really spectacular one. Apart from exciting articles on British wild life, there is an eight-page supplement, and a photographic competition in which all readers can take part.

IN THIS ISSUE:

- **SQUIRREL v. SQUIRREL:** the number of red squirrels is declining – is this due to the introduction of the grey squirrel?
- **WOODLAND BUTTERFLIES**
- **MYSTERIOUS SEA TROUT:** although the sea trout looks like the brown trout, its way of life is completely different.
- **SCOTLAND'S RAREST BIRD:** hooligans nearly exterminated the osprey in Britain.
- **WILD CAT:** Britain's wildest animal has been kept in captivity but never successfully tamed.
- **CATASTROPHE FOR BIRDS:** last winter was probably the biggest disaster for birds since records were kept.
- **EAGLES OVER NORFOLK:** they have their liberty but come home every day for their food.
- **A BIRD IN THE HAND:** making friends with birds in your garden is only a matter of patience and a little know-how.

FREE! *8 PAGE SUPPLEMENT FOR NATIONAL NATURE WEEK*

This supplement will contain:

A MAGNIFICENT photographic study of a swan; a photographic competition for all readers; instructions on how to be an animal photographer; details of the Wildlife Rangers – a movement of young people to save the world's wild life; a country calendar telling you what to look out for in the country in the next four months; a feature on Britain's nature reserves – where Britain's fauna and flora can be seen in their natural state; and finally a country code, telling you how you can be an angel and not a devil in the countryside.

HOW YOU CAN HELP SAVE THE WORLD'S WILD LIFE

This week's issue of *Animals* contains details of the new Wildlife Youth Service. This is the junior branch of the World Wildlife Fund, which is dedicated to saving the world's wild life from extinction. The chairman of both organisations is Peter Scott, the world-famous naturalist. He writes a special message to every boy and girl in Britain in this week's issue of *Animals*. If you want to help the world's wild life, then you will want to join the Wildlife Rangers.

ENTER NOW for the special

PHOTOGRAPHIC COMPETITION

in this week's issue of 'Animals'

****

First prize worth £50 – and many other attractive prizes as well

****

Animals is the new Armand Denis magazine in full colour

PRICE 2/- — EVERY TUESDAY

Letter from the Editor

37 HERTFORD ST.
LONDON W.1

ONCE Britain could be described as a green and pleasant land. Today, much of it is neither green nor pleasant. Parts of it are still beautiful, but its inhabitants are gradually putting an end to this. In the last two centuries the face of Britain has changed fantastically: towns have stretched deep into the countryside, transforming what was once beautiful scenery into a depressing suburbia. Britain's wild life has also suffered. You would be surprised, if you could be transported back two or three hundred years, to find out how many more animals there were in Britain then.

This week has a special importance for those who are worried about the threat to Britain's natural heritage. It is National Nature Week, organised by the Council for Nature, a body set up five years ago to encourage interest in the problem of nature conservation. This week there will be an attempt to bring home to the people of Britain the threat to our wild life.

Another feature of National Nature Week is the launching of a new organisation for young people to help preserve our wild life. It is called the Wildlife Rangers, and the President is my friend Mr Peter Scott, the famous naturalist, whom you may have seen on television. In this week's issue of our other magazine, *Animals*, full details of the Wildlife Rangers are given. I hope that if you are at all interested in animals you will join and take part in some of the exciting activities of this organisation.

John Chancellor

FACTORS
A word game

The following statements are either 'true' or 'false'. When one is 'true' score the *first* number, but if you think that it is 'false' score the *second* number. Change the numbers into letters (1=A; 2=B; and so on). Put these letters into the squares to make a five-letter word reading down the frame.

The empire of the Incas was established in Mexico (23) – (8)
In addition to being a breed of dog, Sealyham is a place in Wales (5) – (1)
The stripes on a sergeant's sleeves are called chevrons (1) – (20)
A rear-admiral is senior in rank to a vice-admiral (5) – (18)
Merino is a fine yarn of sheep's wool (20) – (18)

ANSWER

Heart
(*The Incas lived in Peru, and a vice-admiral is senior in rank.*)

FAMOUS FACES COMPETITION — results

IN the Famous Faces Competition, set in Knowledge News Nos. 111, 59 and 6, dated 17th February, readers were asked to identify eight famous faces, and also to suggest a ninth person who deserved a place in the gallery. There were over 2,000 entries from British readers. They provided an extremely varied selection of suggestions for the ninth face, from Karl Marx to Margot Fonteyn, and from Sir Francis Drake to Elvis Presley. To qualify for a prize all competitors had to identify the famous faces correctly – prizes were awarded to those who gave the best and most concise reasons for choosing the ninth famous face.

THE EIGHT FAMOUS FACES THAT COMPETITORS HAD TO IDENTIFY WERE:

1. JOSEPH STALIN
2. FLORENCE NIGHTINGALE
3. SIR WINSTON CHURCHILL
4. CHARLIE CHAPLIN
5. MARILYN MONROE
6. CHRISTINE TRUMAN
7. QUEEN VICTORIA
8. W. G. GRACE

Albert Schweitzer

'He was born on January 14th, 1875. He was a brilliant musician but he became a doctor of medicine to devote his life to missionary work in Africa. Natives travel hundreds of miles for attention at his hospital at Lambarene.'

First prize: Alan Davey, aged 9.

Nine-year-old Alan Davey of 16 Crofton Lane, Orpington, Kent, is the winner of the first prize – the Macdonald library of English Classics containing over 30 of the greatest books in the English language. Alan suggested Albert Schweitzer as Famous Face No. 9.

Three second prizes of the Macdonald Illustrated Library have been awarded to: Rodney Bush, aged 13, of 7 Colonial Road, Slough, Buckinghamshire, whose choice for Famous Face No. 9 was Sir Alexander Fleming; Jean Grundy, aged 9, of 13 Charles Avenue, Hilltop, Eastwood, Nottinghamshire, who suggested Leonardo da Vinci; and Master T. Homett, aged 15, of 71 Windmill Way, Much Hadham, Hertfordshire, who chose Yuri Gagarin.

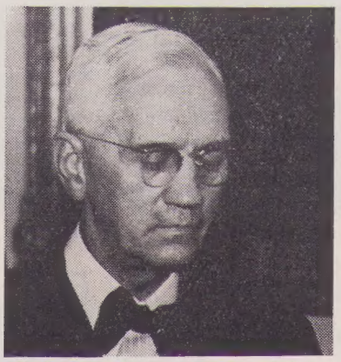
These famous faces are shown here, each with the winning entry beneath.

Leonardo da Vinci

'Leonardo da Vinci is famous for great paintings, marvellous drawings, and the ideas he recorded in his notebooks on natural science, engineering, aeronautics, anatomy, geology and mathematics.'

Second prize: Jean Grundy, aged 9.

Sir Alexander Fleming



'Sir Alexander Fleming was a research doctor. One day he noticed a mysterious mould growing on a glass dish in his laboratory. From it he produced penicillin, which is a powerful germ killer. It has saved thousands of lives.'

Second prize: Rodney Bush, aged 13.

Yuri Gagarin

'No. 9 should contain the photograph of the Russian astronaut, Yuri Gagarin, as he was the pioneer of space travel. Your gallery of famous faces deals only with the past and present; Gagarin represents the future in which man will strive to explore the universe.'

Second prize: T. Homett, aged 15.

TEN THIRD PRIZES OF 'THE STORY OF PREHISTORIC ANIMALS' for the following:

'Marco Polo, a native of Venice, was a great 13th-century traveller. He wrote an account of his travels to Mesopotamia, Persia and China. He travelled to China with his father and uncle where he was presented with a kingdom.'

Carol Ahern (age 13),
34 Rivacre Brow, Overpool,
Ellesmere Port, Cheshire.

'As the Red Cross is celebrating Centenary Year, the missing person must be Jean Henri Dunant, founder of the Red Cross Society. At the battle of Solferino, Italy, he had the idea of giving aid to the wounded and dying.'

Avril Peebles (age 12),
8 River Terrace,
Guardbridge, Fife.

'Albert Einstein: born 1879, died 1955. One of the most profound thinkers of our time. His theories of relativity, of the size of the universe, of gravitation and inertia brought him fame. A leader in the investigation of atomic energy.'

Jean Johnson (age 16),
New House Farm, Ightfield,
Whitchurch, Shropshire.

'William Wilberforce was a Yorkshireman. He was educated at Cambridge and entered Parliament when he was 21. He fought for the abolition of slavery, and in 1807 the Act for the abolition of slavery was passed.'

David Crawford (age 10),
28 Bilton Lane,
Harrogate, Yorkshire.

'My choice is the great German composer, Ludwig van Beethoven, who became deaf at an early age and never heard many of his own works, which today give pleasure to millions of people.'

Linda Grimes (age 13),
4 Cedar Hill,
Epsom, Surrey.

'Mahatma Gandhi is famous for the way he resisted the British in India by his principle of Ahimsa. The success of his non-violent methods made his name famous, and his personal holiness earned him universal respect.'

Robert Flanagan (age 15),
4 Walsingham Avenue,
West Didsbury, Manchester 20.

'Lord Baden Powell helped to make boys good citizens by giving them the Scout Promise, asking them to respect God, the Queen and their parents. The present size and popularity of the movement is a fitting tribute to this great man.'

Philip Powell (age 9),
32 Thomasville,
Penyrheol, Caerphilly.

'William Shakespeare is famous for his poems, sonnets and dramatic plays. His works included comedies, tragedies and histories.'

Stephen Pike (age 12),
76 Parkland Drive,
Oadby, Leicester.

'Sir Edmund Hillary is well known for his mountaineering experiences, but the climb that made him famous was the conquest of Mount Everest, the highest mountain in the world.'

Ian Sims (age 13),
Cloverlea, Pedlars End,
Moreton, Nr Ongar, Essex.

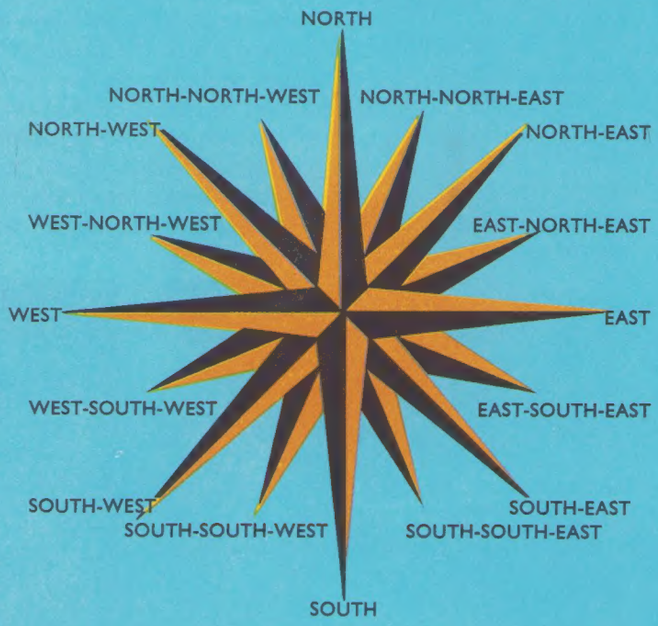
'For picture No. 9 I suggest Marie Curie. Her research on radium and radioactivity has brought relief to many sufferers from cancer. She is one of the few really great women scientists.'

Carol Pye (age 12),
13 Furness Avenue, Hard Lane,
St Helens, Lancashire.

THE COMPASS

A NAVIGATOR or a surveyor is able to measure direction by means of a magnetic or gyroscopic compass (see page 367); and the course of a ship or aircraft, and bearings measured from one point to others, are given as the angle measured clockwise from North in degrees. But this method of reporting direction is comparatively new. Even a century ago the captain of a sailing ship always used the *Points of the Compass* to describe direction. This method had been used with little change since the 13th century, and, indeed, the general idea of direction which is given by the points of the compass is probably very much older.

When a traveller on land is uncertain of his way, he has only to ask some passer-by which road or track to take. Because he never has occasion to consult the sky it is difficult for him to imagine how the seaman can make his way across the pathless ocean waters. Historians, confronted with the fact that long voyages were undoubtedly made in ancient times, said that before he had the magnetic compass the sailor 'hugged the shore' and crept along the coast from harbour to harbour. It is true, of course, that there was coastal sailing, but every sailor has a dread of being driven ashore and, if possible, sails well out to sea to avoid the dangers of inshore rocks and shoals. This means that he is frequently out of sight of land and must therefore know the right direction to steer in order to reach his destination.



In the days before the compass, the sailor relied upon two kinds of information to tell him about direction. The first was the movements of the sun and stars; the second was the quarter from which the wind was blowing and the types of weather associated with the different wind directions. When we travel north or complain of an east wind, we are thinking in terms of four whole quarters of horizon and sky and not of 'lines' or 'points', and this lack of precision was characteristic of navigation in the times before the compass was discovered.

It is possible to divide the sky according to the apparent movements of the sun and stars. The most important directions defined in this way are those of sunrise and sunset, and the position of the sun at noon.

At night, of course, the apparent movements of the stars provide much additional information about direction. You will see (page 1978) that the rotation of the earth causes an apparent rotation of the celestial sphere about its poles. In ancient times men realised that a star near the celestial pole stayed in more or less the same position throughout the night, and so they could take their direction more accurately from this star than from any other.

THE POINTS OF THE COMPASS

The first magnetic compasses began to be used in Europe about the beginning of the 13th century. The greater accuracy with which direction could now be measured led to further division of the circle beyond the eight points (North, North-east, East, South-east, South, South-west, West, and North-west) which had been used in Ancient Greece.

Since there are four cardinal directions and each successive subdivision bisects the angle between the points on either side of it, the subdivision of the compass rose proceeds from the 8-point circle (with angles between the points of 45°), through the 16-point ($22\frac{1}{2}$°), illustrated here, to the 32-point compass rose which forms an angle of $11\frac{1}{4}$° between adjacent points.

In the days of sailing ships, the captain would always speak of the ship's course being 'nor-nor-west' or say that a rock had a bearing 'nor-west by north'. Apprentice seamen of those days used to be ordered to 'box the compass' or to repeat the 32 points of the compass in their correct order. The actual appearance of the compass rose (or wind rose as it was sometimes called) is usually of the pattern illustrated here. Similar compass roses appear on the earliest known navigation charts, and they are often still seen on the cards of modern compasses. Usually the compass rose has the form of an ornate star. It is possible that this pattern is a reflection of the great importance of the stars in finding directions before the discovery of the magnetic compass and, indeed, of the fact that the compass needle pointed approximately towards the north star, Polaris, which men had come to rely on as the most reliable astronomical indication of direction.

We know that the 32-point system was used by English sailors at the time of Chaucer (about 1390) and that it has been used until recent times. However, the angular difference of $11\frac{1}{4}$° between successive points means that this, by itself, is a rather crude method of measuring direction. Today very precise navigation is needed for large, fast ships and aircraft, and the 360° (or *sexagesimal*) system used by surveyors, and the continental 400^g (or *centesimal*) system in which each right angle is divided into 100 *grades*, are used.

WIND AND DIRECTION

The early ideas about direction were closely tied to observations of wind and weather. Indeed for many centuries the word 'wind' was often used in the sense of 'direction' in nautical language. Because wind and weather are so closely related, the kind of weather depends very closely upon the quarter from which the wind blows. It follows that the 'feel' of the wind gives a rough indication of direction. The simplest observation is that cold air comes from the north, warm air from the south. Hence the Ancient Greek names for these winds, *Boreas* and *Notus*, were also those for north and south respectively. On the Tower of the Winds, in Athens, the eight sides of the ruin are known by the eight directions and their associated winds: *Boreas* (N), *Kaikas* (NE), *Apeliotes* (E), *Eurus* (SE), *Notus* (S), *Lips* (SW), *Zephyrus* (W) and *Skiron* (NW).

HIPPOCRATES

I SWEAR BY APOLLO THE PHYSICIAN, AND AESCULAPIUS, AND HYGEIA, AND PANACEA, AND ALL THE GODS AND GODDESSES, THAT, ACCORDING TO MY ABILITY AND JUDGEMENT, I WILL KEEP THIS OATH. . . .

I WILL FOLLOW THAT SYSTEM OF TREATMENT WHICH, ACCORDING TO MY ABILITY AND JUDGEMENT, I CONSIDER FOR THE BENEFIT OF MY PATIENTS, AND ABSTAIN FROM WHATEVER IS DELETERIOUS AND MISCHIEVOUS. I WILL GIVE NO DEADLY MEDICINE IF ASKED, NOR SUGGEST ANY SUCH COUNSEL. . . .

INTO WHATEVER HOUSES I ENTER, I WILL GO INTO THEM FOR THE BENEFIT OF THE SICK, AND WILL ABSTAIN FROM EVERY VOLUNTARY ACT OF MISCHIEF. . . .

WHATEVER, IN CONNECTION WITH MY PROFESSIONAL PRACTICE, OR NOT IN CONNECTION WITH IT, I SEE OR HEAR, IN THE LIFE OF MAN, WHICH OUGHT NOT TO BE SPOKEN OF ABROAD, I WILL NOT DIVULGE. . . .

WHILE I CONTINUE TO KEEP THIS OATH UNVIOLATED, MAY IT BE GRANTED TO ME TO ENJOY LIFE AND THE PRACTICE OF THE ART, RESPECTED, BY ALL MEN, IN ALL TIMES. BUT SHOULD I TRESPASS AND VIOLATE THIS OATH, MAY THE REVERSE BE MY LOT.

Hippocrates, the greatest doctor of antiquity, operates on the skull of one of his patients. Primitive man frequently made holes in the skull 'to let out evil spirits' which were thought to cause diseases like epilepsy and madness. Later the operation was used largely in the treatment of fractures of the skull

THESE lines are part of the *Hippocratic Oath*, the Oath which for 2,000 years has governed the professional and the social behaviour of doctors. Strangely enough, although the Oath probably represents Hippocrates's views very well, it was almost certainly not written by him. Indeed, there is evidence that some parts of the Oath come from Ancient Egyptian medical practice, and there is also evidence that other parts were compiled only after Hippocrates's death.

Quite obviously the Oath was intended both for students and for experienced practitioners of medicine. With the passing of 2,000 years, however, parts of the Oath have become outdated. Nowadays, although doctors still adhere to its spirit, there are occasions when its details are ignored. In Courts of Law, for instance, doctors are often obliged to disclose details of their patients which the Oath would certainly regard as secret.

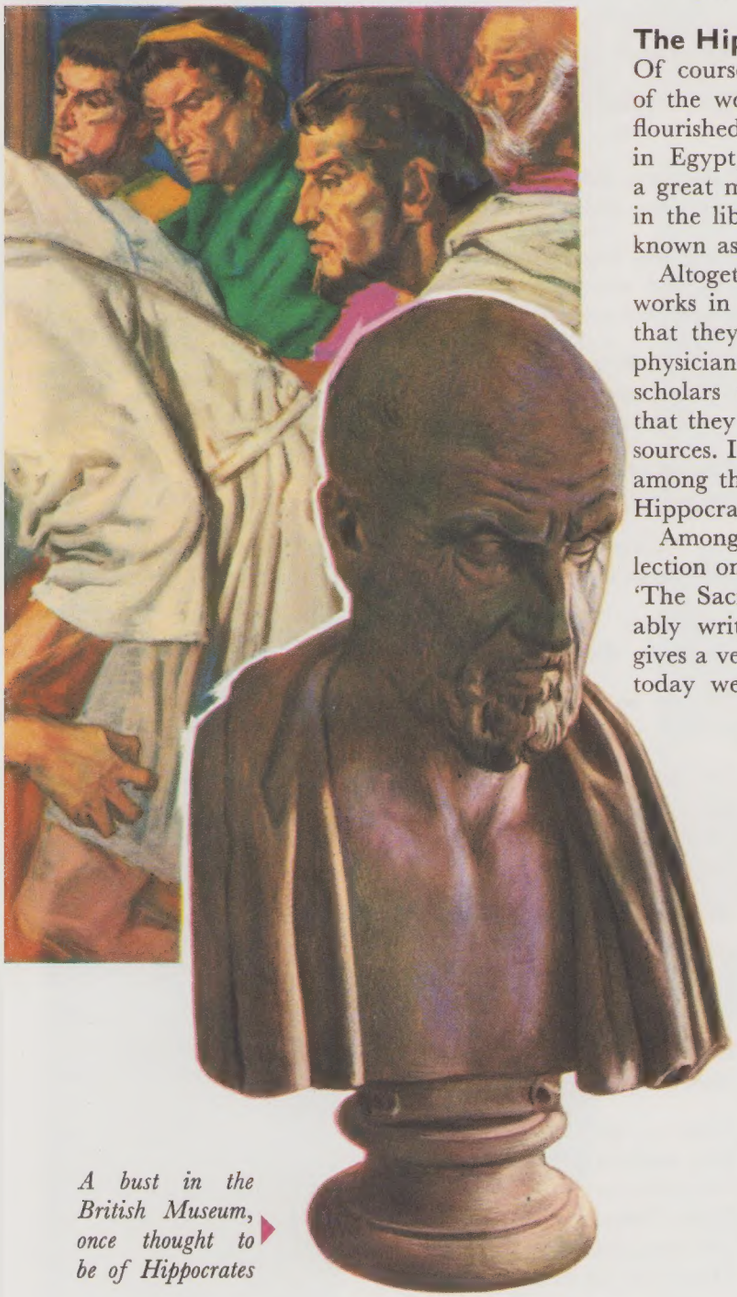
Although Hippocrates is one of the great figures in history, it must be admitted that we know almost nothing about him. We do know, however, with reasonable certainty, that he was born on the little island of Cos, in the Aegean, in the year 460 B C. Some historians would have us believe that it was here that he studied the art of medicine, and later taught his pupils. Indeed, there is to this day in the centre of the town of Cos a plane tree, under which, so it is said, Hippocrates lectured.

It seems likely, too, that Hippocrates taught on the mainland of Greece, and that he visited Athens. He died at Larissa, and though we know that he was then very old, between 85 and 110, even the exact date of his death is unknown.

The Hippocratic method

Greek medicine before Hippocrates was based largely on magic, superstition, and religious rituals. Some diseases were, in fact, believed to be punishments wreaked upon unfortunate humans by the vengeful gods. Hippocrates thoroughly disapproved of these ideas, and throughout his life he taught and argued that all diseases had natural, not supernatural, causes. In this view, as in many others, modern medicine has proved him to be right.

Among the benefits that he brought to medical practice was his insistence that a doctor should always study his patients carefully, and so learn about the appearance and the course of every illness. In this way the doctor could learn how each disease progressed, and would thereafter be able to forecast the outcome of similar cases accurately.



A bust in the British Museum, once thought to be of Hippocrates

Hippocrates used only a few simple drugs, for his faith lay in the ability of the body to recover by itself. This he called 'The Healing Force of Nature'. While Nature was doing the healing, however, the diet which Hippocrates ordered was often, to our minds, very strict. It was merely gruel made from barley; with honey and water, or honey and vinegar, to drink.

Although chiefly a physician, Hippocrates did not disdain surgery. He treated fractures and dislocations, incised abscesses, and, as we can see in the illustration, did complicated operations on the skull in cases of head injury. Some of his advice to surgeons is still very applicable today: 'The nails should be neither longer nor shorter than the points of the fingers. One should practise all sorts of work with both hands, endeavouring to do it well, elegantly, quickly, neatly, and promptly.'

The Hippocratic Collection

Of course, Greece was not the only part of the world in which the art of medicine flourished in ancient times. At Alexandria, in Egypt, a medical school grew up, and a great many medical works were collected in the library there. Some of these became known as the Hippocratic Collection.

Altogether there were between 70 and 100 works in this Collection, and the idea was that they were the preserved works of the physician from Cos. However, even the early scholars who studied these books realised that they came from a great many different sources. Indeed it is doubtful if any one book among them can be definitely attributed to Hippocrates.

Among the books in the Hippocratic Collection one of the most famous is that called 'The Sacred Disease'. This book was probably written as early as 400 B C, and it gives a very clear account of the disease that today we call epilepsy. At that time this illness was generally thought to be one of the diseases caused by the irate gods. It is for this reason that it came to be called 'sacred'. Although the author of the book does not know the real cause of epilepsy, he obviously has no doubt that it is the result of quite natural causes.

Several of the books in the Collection are written in a very special style. It is called the *aphoristic style*. An aphorism is a short and easily remembered sentence which contains an important observation or instruction. Needless to say, most of the aphorisms in the Collection are concerned with the problems of diagnosis and treatment.

SOME PASSAGES FROM THE HIPPOCRATIC COLLECTION

Medicine is of all the Arts the most noble; but, owing to the ignorance of those who practise it, and of those who, inconsiderately, form a judgement of them, it is at present far behind all the other Arts.

Life is short and the Art [of Medicine] long; the occasion fleeting; experience fallacious, and judgement difficult.

Those diseases which medicines do not cure, the knife cures; those which the knife cannot cure, fire cures; and those which fire cannot cure are to be reckoned wholly incurable.

For extreme diseases, extreme methods of cure . . . are the most suitable.

Persons who are naturally very fat are apt to die earlier than those who are slender.

It is thus with regard to the disease called Sacred: it appears to me to be nowise more divine nor more sacred than other diseases, but has a natural cause from which it originates like other diseases.

One ought to be well aware that every bandage has a tendency to fall off towards the part that declines or becomes smaller; as, for example, upwards, in the case of the head, and downwards, in the case of the leg.

It deserves to be known how a shoulder which is subject to frequent dislocations should be treated. For many persons owing to this accident have been obliged to abandon gymnastic exercises, though otherwise well qualified for them; and from the same misfortune have become inept at warlike practices, and have thus perished. And this subject deserves to be noticed, because I have never known any physician treat the case properly; some abandon the attempt altogether, and others hold opinions and practise the very reverse of which is necessary.

There are many varieties of curvature of the spine even in persons who are in good health; for it takes place from natural conformation and from habit, and the spine is liable to be bent from old age, and from pain.

THE DISCOVERY OF METALS

PREHISTORY is divided by archaeologists into three ages: the Stone Age, the Bronze Age, and the Iron Age. During the Stone Age all man's tools and weapons were made of stone (usually flint), except for a few made from wood, bone, and horn. Although primitive man became very skilful in shaping flint to make axes, knives, saws, sickles, and arrowheads, the objects he made from stone were crude ones. They were brittle, and took many hours to make; and stone knives did not cut very well.

About five thousand years ago, however, man discovered how to produce a new material. This was copper, the first metal, and it introduced a new era.

INTRODUCTION OF METALS

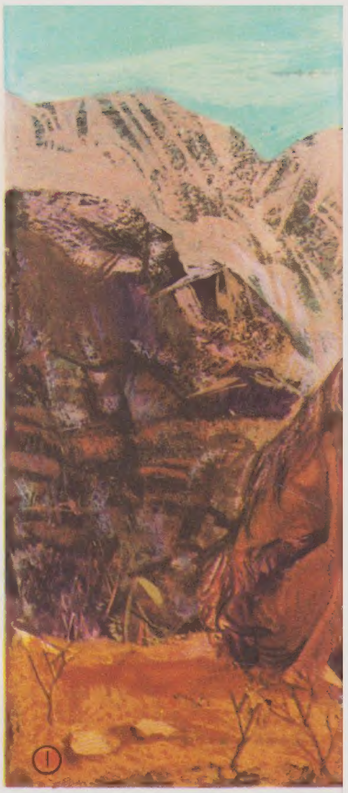
A few metals – gold, silver, meteoric iron, and (rarely) copper – are found free in nature. These *native* metals were very precious and were used by their lucky finders to make only jewellery and ornaments.

About 3500 B C, somewhere in the Middle East, a man built a fireplace of stones. The fire he lit made the stones very hot – so hot, in fact, that they melted. When the fire died down the man found to his surprise that the melted stones had turned into something that was no longer hard and brittle and difficult to work. Instead, he found something strong which could be hammered into all sorts of shapes. Above all, it was something that could be remelted and cast in moulds to make any number of objects of the same shape. By an accident like this a metal, in this case copper, was smelted for the first time. (Changing a metallic ore into metal by the use of heat is called smelting.)

No doubt men began to experiment with other stones, and soon tin, another easily smelted metal, was obtained. By mixing tin and copper, bronze – a harder and stronger metal – was made, and the Bronze Age began.

SOME DATES IN THE HISTORY OF METALS

5000 B C or earlier	The Middle East	Grave ornaments and jewellery were made from native gold, silver, and copper.
4000 B C – 3500 B C	The Middle East	It was discovered that metals could be melted and cast in moulds, and that copper could be hardened by hammering it.
3500 B C – 3000 B C	The Middle East	Man discovered that copper could be obtained from ores by smelting.
3000 B C	Egypt	Gold ore was crushed to powder and the gold grains extracted by washing (see page 2).
3000 B C	Egypt	The first articles were made from bronze.
3000 B C – 2500 B C	The Middle East	Saws, nails, knives, needles, and axes were made from copper.
3000 B C – 2500 B C	Asia Minor	Silver was being obtained from the lead ore *galena*, and lead was probably known.
2500 B C	Caucasus, Asia Minor, Persia	Tin was being mined on a large scale. Copper mining became a major industry.
2000 B C	Europe	The use of metals became widespread throughout Europe.
1800 B C – 1500 B C	Near East	The Hittites were using objects made from meteoric iron.
1500 B C	Syria, Near East	Iron tools and weapons appeared for the first time.
1000 B C	Great Britain	Tin was being mined in Cornwall.
1000 B C	Italy, Europe	The Etruscans mined iron ore and produced iron in large quantities. The Iron Age began in Europe.
700 B C	Greece, Near East	Silver was mined in Greece, and gold and silver were used as currency in the Near East.
700 B C	Europe	Ploughs, harrows, and other tools for farming were made of iron.
Roman times	Europe	Brass, an alloy of copper and zinc, was first used, and mercury was extracted from its ores in Spain. Pewter, an alloy of tin and lead, was used in making objects for use in the home.



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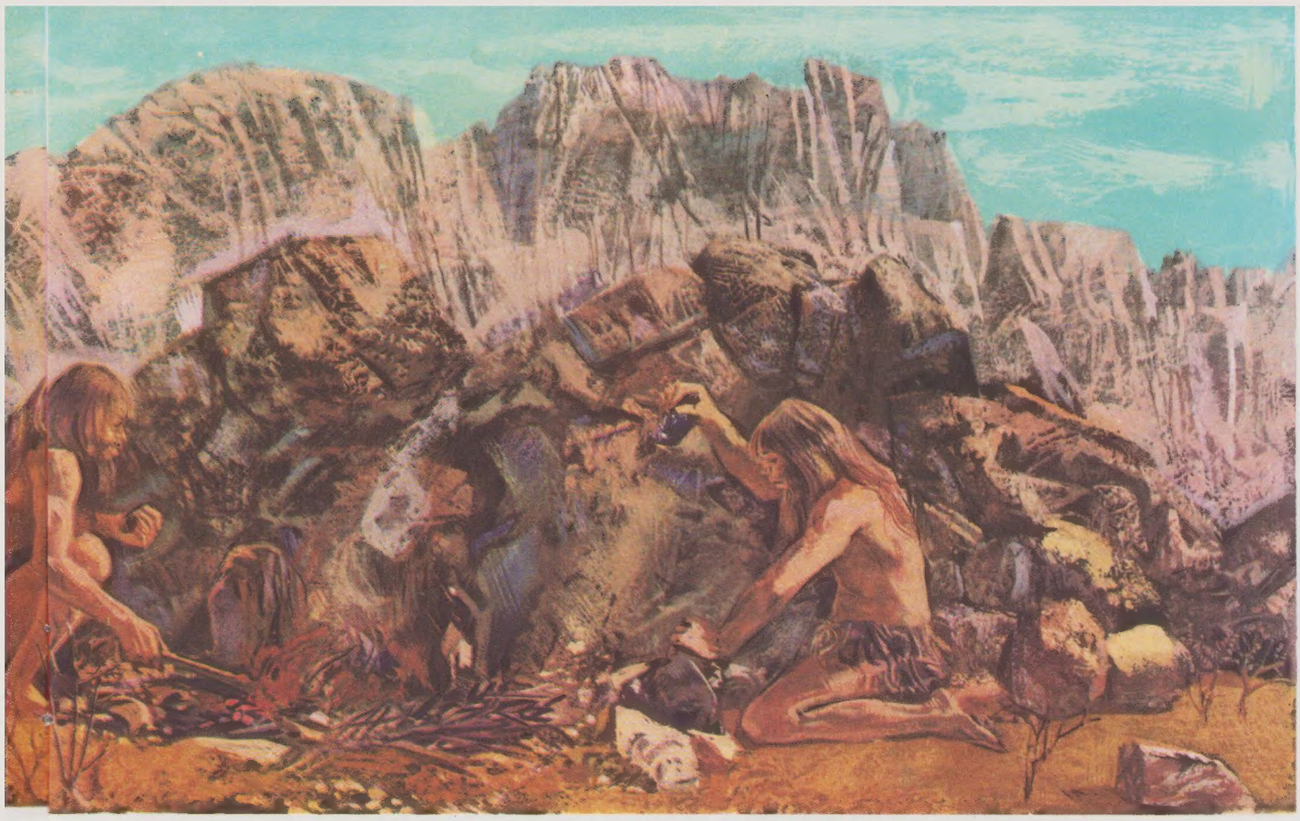
A LITTLE CHEMISTRY

Many of the common ores of metals are oxides, carbonates, or sulphides. Copper and tin, the two earliest metals to be smelted by man, are often found as oxide ores; that is, the metal is combined with oxygen. The oxygen must be removed from the ore to free the metal, and the simplest way to do this is to heat the ore with carbon. The carbon combines with the oxygen and forms the gas carbon dioxide, leaving the metal behind.

Since carbon is formed by the burning of wood, metal ores which lose oxygen easily can be converted to the metal by heating in a wood fire. Copper and tin are two such metals.

Iron does not melt at a temperature that can be reached in a wood fire, and its ore is not reduced to the metal as easily as the ores of tin and copper. For these reasons, men did not discover how to smelt iron until about 1500 B C.



① These two Bronze Age men are smelting copper. They have made a small pit in the ground and have dug a tunnel to the bottom of the pit to allow air to get to the fire which they have lit in it. The man on the right is breaking the ore into small pieces while the man on the left tends the fire. The copper will collect in a pool at the bottom of the pit, and when it is cold the lump of metal will be removed.

The production of copper from its ore as carried out about 3000–2500 B C

② Bronze was obtained either by melting together a mixture of copper and tin or by smelting in the same fire a mixture of copper and tin ores. Bronze was better than pure copper for many purposes, and was very widely used by about 2000 B C. In this picture bronze is being melted in a crucible over a fire which is being blown by a pair of foot-operated bellows. On the left molten bronze is being cast in a mould.

The process of bronze casting as it was carried out in Egypt about 1750 B C

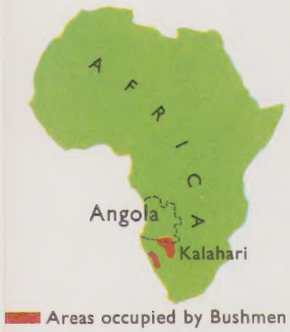
③ Because of the very high temperature needed to convert iron ore to iron an open fire is not hot enough, and a furnace must be used. The Etruscans stacked ore in layers alternately with charcoal, and a clay tower was built round the heap. The charcoal was lit, and air entered the furnace through holes at the bottom. A spongy mass of iron was obtained, which was then hammered to beat out the impurities and form a solid lump of iron.

An Etruscan iron-making furnace of about 1000 B C

Moulds for the production of spearheads, bodkins, and sickles

Bronze objects made from moulds like those shown on the left: ①, a scraper; ②, a bodkin; ③, various axes; ④, a sickle; ⑤, a spearhead

BUSHMEN OF THE KALAHARI



IN south-west Africa there is a huge expanse of desert and wild grassland, or *veld*, stretching from the Okovango River in the north to the Orange River in the south. It is the Kalahari Desert, three times the size of Britain, a land of great plains and sand-dunes, rough grass and thorns and stones. It has no streams, only waterholes, and no tall trees except the giant baobab trees, growing far apart from each other. Rain falls from December to February, but during March the land dries up and the long drought begins. The only moisture is in waterholes hidden deep in earth and long grass. By August even these are dry.

The inhabitants of the desert

This harsh country is the home of the Bushmen, survivors of a race which once lived and hunted all over South Africa. About 20,000 Bushmen live in south-west Africa and another 30,000 in the Bechuanaland Protectorate. Half of these live as hunters and food gatherers roaming the veld. The others work on European farms or for Bantu tribes.

No one knows how long the Bushmen have lived in Africa. The Bantu races, moving south, drove the Bushmen into the desert and at the same time they were hemmed in by the Europeans (now Afrikaners) who landed at the Cape in 1652 and gradually moved north to the Orange River.

The Bushmen are among the most primitive people surviving on earth. They hardly ever fight among themselves, and would rather run away or hide than defend themselves by force. Their only effective weapons are bows and poisoned arrows, and they were no match for the warlike Bantu tribes or for the Afrikaners. For 200 years, all along the European frontier, Bushmen were hunted down, and when they struck back by stealing or killing cattle, the Afrikaners organised raids against them. The Bushmen who survived this deadly warfare lost their ancient hunting grounds and were driven back into the Kalahari.

Bushmen are small, with long, slender arms and legs and finely-modelled hands and feet, the men a few inches over 5 feet and the women a little shorter. They have golden-brown skins, and when young they are beautiful, with heart-shaped faces, narrow, long-sighted, deep-brown eyes, and curly black hair. They are tough and lithe, extremely graceful, and very fast runners. As they grow old their skin becomes deeply creased and their faces wrinkled. The men wear leather loincloths, and the women leather aprons and capes made of hide, which form pouches in which their babies can ride, and empty ostrich eggs can be carried as water containers. They wear white eggshell beads in their hair and round their arms and knees, and sometimes leather sandals.

Head of a young Bushman

Bushmen have no written language and can count only up to three or four. Their speech is full of clicking and grunting sounds, with gestures and miming. They live in family circles, like Australian aborigines (see pages 865–867). Sometimes several families live together, each group keeping to its own hunting grounds.

Bushmen keep no flocks or herds, for there is not enough water to keep animals alive through the drought. They cannot stay anywhere long enough to tend crops or wait for them to grow, for the supply of wild food is quickly used up and they have to move on. They live in shelters made of grass and branches, with their fires placed near them, and often sleep in the grass.

Bushmen are skilled hunters of antelope like gemsbok and springbok. They use tiny arrows of metal or bone dipped in deadly poison extracted from grubs and snake glands. A white man alone in the Kalahari would die of starvation, but Bushmen find and eat 56 kinds of roots (which store liquid to preserve the plant's life), stalks, leaves, fruits, berries, nuts, and seeds, as well as ants, caterpillars, and tortoises. The women dig up roots with long, pointed sticks, and collect grass seed which they grind in wooden bowls to make porridge. Melons provide food and drink, and in the hottest season many Bushmen keep alive on *bi* (a fibrous, watery root), wild cucumbers, and berries. They sometimes obtain moisture by digging deep in dry water holes to where the sand is still damp, then sucking through a hollow reed bound with grass and so creating a vacuum where a little water can collect. They love honey, which they take by smoking the wild bees out of their nests, but they are careful not to harm the bees, which they think have magic powers.

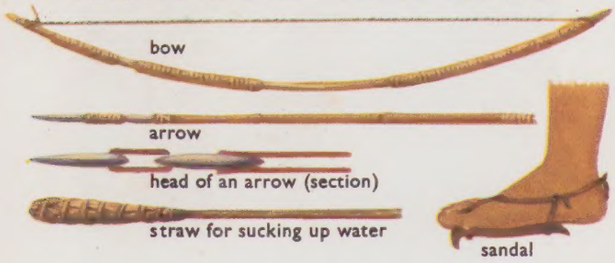
Songs and dances

The Bushman's life would be incomplete without songs and dances. They dance to celebrate a hunt, a marriage, or initiation, to bring rain, and when the moon is full. Their songs are often wordless, accompanied by rhythmic clapping, rattling dry cocoons strung together, playing with a reed on the strings of a hunting bow, or on a flat piece of wood with metal prongs placed on a melon rind; the prongs, when plucked, vibrate and ring. Medicine songs and dances are a solemn ritual, for the medicine men fall into trances and, with the help of the spirits, drive evil, drought, and starvation away.

Once Bushmen were artists too. Throughout South Africa paintings and engravings centuries old are found on rocks and in caves, which are believed to be the work of Bushmen, who still scratch designs on tree bark and ostrich shells. Within living memory Bushmen painters have been found with zebra-hide straps round their waists and, attached to them, ten little horns filled with paint.

A Bushman's shelter

OBJECTS IN DAILY USE BY BUSHMEN



Map showing the distribution of flightless birds, including some which are extinct

BIRDS WHICH CANNOT FLY

EVERYBODY has seen pictures of ostriches and penguins, and many of us have seen them living in zoos. They are birds, but they cannot fly, and there are many other species of birds which are not able to fly. Although there has been some argument on this point, scientists now agree that all these flightless birds are descended, in the evolutionary sense, from birds which could fly. The power of flight seems so precious and valuable to a bird that it is strange that a number of them should have lost it.

Why are they unable to fly?

Flightless birds include species that live in the sea and on land. The only sea birds alive now that are entirely unable to fly are the penguins. These feed on fish, and probably lost their ability to fly while they were developing the ability to swim.

The land birds that cannot fly are either very big or live on islands. The reason for this is that small or moderately sized birds cannot survive without the power of flight in places where there are beasts of prey. Up to quite recent times, there was a variety of flightless birds on the islands of the Mauritius group in the Indian Ocean. The remote ancestors of these birds had arrived on the islands by flying, settled there, and lost the power of flight because there were no carnivorous animals to prey on them. The most famous of these was the dodo, which was a kind of pigeon. But the flightless birds were so pathetically easy to kill that when men came to the islands, with their pigs and dogs, all these interesting but helpless birds became extinct.

Large flightless birds, like the ostrich and rhea, are able to live where there are beasts of prey because they are very fast runners, and can defend themselves against small animals. In New Zealand, where there are no native beasts of prey, there used to be gigantic as well as small flightless birds, but none of the large ones now survives.

MANY OF THEM ARE EXTINCT

Many species of flightless birds have been exterminated by man over the centuries. A recently exterminated species was the great auk, which was a sea bird and lived on some of the islands of the north Atlantic. It looked rather like a penguin. Some of those which became extinct in earlier times were enormous creatures. Biggest of all was the 'elephant bird' of Madagascar, *Aepyornis titan*. This was an ostrich-like bird, 9 or 10 feet tall and very heavily built. A number of its eggs have been found; when fresh they weighed about 18 pounds each.

The most famous of the giant extinct birds, however, are the moas of New Zealand, the largest of which, *Dinornis maximus*, was 12 feet tall – taller than the 'elephant bird', though less massive. They were made known to science in 1839 by the discovery of a single thigh bone, which was examined by Richard Owen, the first Director of the Natural History Museum. He recognised it as that of a gigantic bird of the ostrich type and gave it the name *Dinornis*, which means 'huge bird', just as Dinosaur means 'huge reptile'. Remains of moas and their eggs have been found in Maori refuse heaps, and even rock-paintings of them are known.

Reconstruction of a moa compared with a man

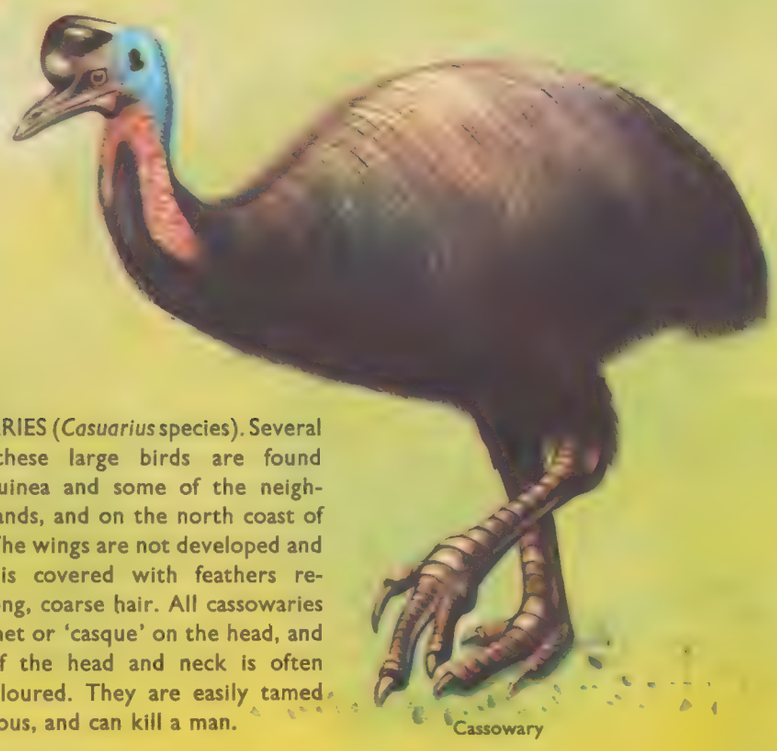
OSTRICH (*Struthio camelus*). This is the largest living bird, and is peculiar in having only two toes on each foot, so large that they are almost hooves. The males are black with white wing and tail feathers, the females are grey. Ostriches live in open, semi-desert country and are now found only in the African continent; they used to live in Arabia and Syria but have been exterminated there. They are very fast runners and can reach speeds of up to 40 m p h with strides of 15 feet. A male ostrich has three or four wives who all lay in the same nest. Ostriches are easy to keep in captivity and the ornamental 'plumes' can be plucked from the birds without hurting them.

Ostrich

EMU (*Dromiceius novaehollandiae*). This is the second largest living bird. Until recently there were several species in Australia and Tasmania, but only one now survives. The emu is found in eastern Australia and is disliked by farmers because it lives on grass, competing with their cattle for grazing. Long fences are made to keep the emus out of rich grazing grounds. The plumage consists of soft, drooping, brown feathers; the eggs are black.

Emu

KIWI (*Apteryx australis*). The kiwis are among the few flightless birds of New Zealand that have survived the onslaught of man. The common kiwi lives in both the North and South Islands, and there are two other species in the South Island. They differ from all other birds in having their nostrils near the tip of the beak; they have a keen sense of smell and feed by probing in the ground for worms. The wings cannot be seen outside the body. Kiwis lay enormous eggs, for one egg may weigh a quarter as much as the bird which laid it. Usually only one is laid at a time, and the incubation, which takes between two and three months, is performed by the male.



Cassowary

CASSOWARIES (*Casuarius* species). Several kinds of these large birds are found in New Guinea and some of the neighbouring islands, and on the north coast of Australia. The wings are not developed and the body is covered with feathers resembling long, coarse hair. All cassowaries have a helmet or 'casque' on the head, and the skin of the head and neck is often brightly coloured. They are easily tamed but dangerous, and can kill a man.

Kiwi

Owl parrot

KAGU (*Rhinochetus jubatus*). This bird is found only in the island of New Caledonia. It is now confined to the mountains of the interior and is in grave danger of extinction. Its wings are quite well developed but not strong enough to enable the bird to fly. The kagu is as big as a heron and probably related to the cranes.

OWL PARROT (*Strigops habroptilus*). This curious bird is found in the forests of the North Island of New Zealand. It is a member of the parrot family that has lost the power of flight and is *nocturnal* in its habits – that is, active by night. It is for this reason, of course, that it has been given the name owl parrot.

It climbs about in the trees, using its wings to help it in making long hops from one branch to another. It is a vegetable feeder and nests in holes in trees, laying two or three eggs at a time.

Kagu

Takahe

Weka

WEKA (*Gallirallus australis*). This is a New Zealand bird about the size of a chicken. It sleeps by day in a burrow, and comes out at night to hunt for rats, mice, and other small creatures.

TAKAHE (*Notornis hochstetteri*). Another New Zealand bird, the takahe, is really a kind of large coot. It was thought to be extinct long ago, but in 1948 a small colony, probably of less than 50 birds, was discovered in a remote part of the South Island.

RHEA (*Rhea americana*). The rhea is sometimes called the 'ostrich of the pampas'. It is smaller, brownish-grey in colour, and has three toes, but its habits are rather similar to those of the African bird. Here again the male has several wives and they all lay in one nest, which may finally contain as many as 60 eggs. The male does all the work of incubating them and looking after the young when they hatch, and he defends them with great courage. The common rhea is found in the pampas country of Argentina and Brazil.

Rhea

MOVEMENT OF THE EARTH (part two)

THE second important movement of the Earth is its revolution about the Sun. This is because the Earth is a satellite, and is therefore subject to the gravitational attraction of the Sun. Like all the other planets of the solar system, the Earth has an orbit which traces the circumference of an ellipse. This is Kepler's First Law (see page 523).

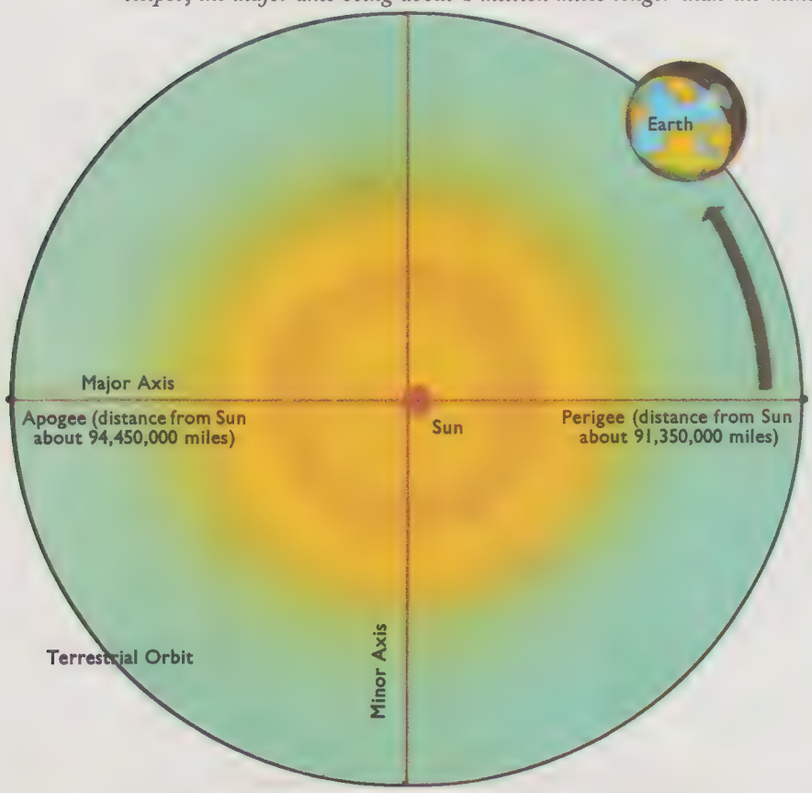
The geometry of an ellipse

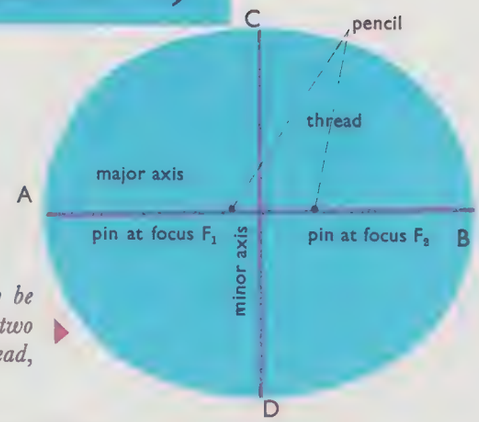
We can construct an ellipse by fixing two pins through a piece of paper, placing a loop of thread over them, and holding a pencil within the loop so that this forms the third point in a triangle of thread. If the pencil is now moved in such a way that the thread remains tight, it will trace the circumference of an ellipse. The shape and size of the ellipse may be defined by its major axis (AB) and minor axis (CD) which are perpendicular straight lines meeting at the centre. The two pins will lie on the major axis and these two points are known as the *foci* of the ellipse (the points shown as F_1 and F_2 in the illustration are the two foci). If P is the pencil point on the circumference of the ellipse, the sum of the distances F_1P+F_2P will be the same for all positions of P.

Perigee and apogee

From Kepler's First Law we suppose that the Sun is situated at one focus of the ellipse which is traced by the Earth as it moves in its orbit. Because the distance from A to F_2 is greater than from B to F_2, the distance between the Sun and the Earth varies during the course of the year. The time when the Earth is farthest away is known as Apogee (or Aphelion) and occurs on 2nd January. The Earth is then about 94,450,000 miles from the Sun. The Earth lies nearest the Sun on 1st July, when the distance is about 91,350,000 miles. This phase is known as Perigee or Perihelion. The average speed of the Earth along its orbit is about 66,600 m p h, but, as shown by Kepler's Second Law, the orbital speed varies. It is greatest when the Earth is nearest the Sun and least when the Earth is in Apogee.

The orbit of the Earth round the Sun describes the circumference of an ellipse, the major axis being about 1 million miles longer than the minor





How an ellipse may be drawn by means of two pins, a loop of thread, and a pencil

Some ideas about time

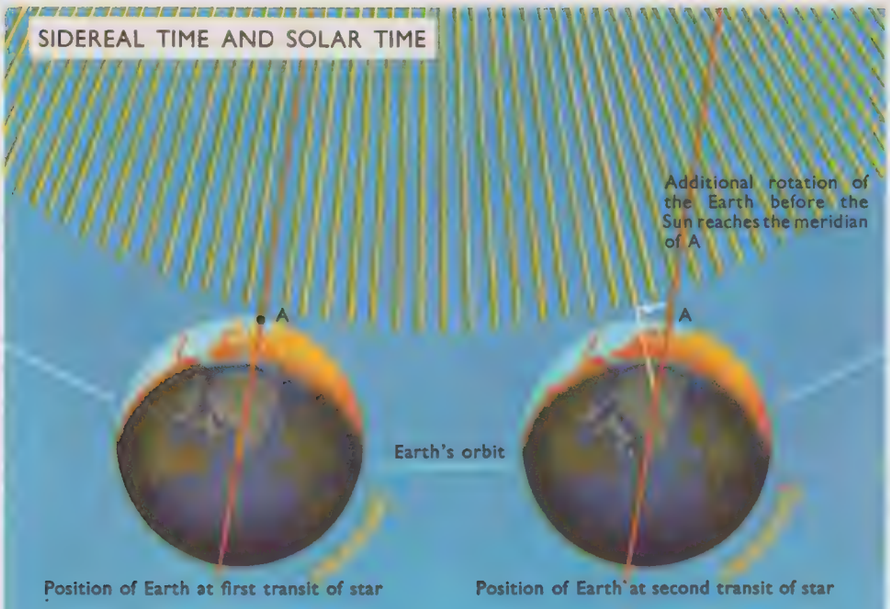
We have seen that the rotation of the Earth about its own axis takes one day, and the revolution of the Earth about the Sun takes one year. However, neither of these is a precise value of 24 hours or 365 days. We must understand in what way they are different from the figures which are usually adopted for the *Civil Day* and *Civil Year* kept by our clocks, and printed in our calendars and diaries.

Let us first of all think about the daily rotation of the Earth. This motion is *uniform*, or, in other words, the Earth continues to rotate at the same speed throughout the 24-hour period. As we saw in the last article, it seems to an observer on the Earth that the celestial sphere rotates. This motion, too, appears to be uniform if we watch the apparent movement of heavenly bodies which do not belong to the solar system, and every star will, at some time of the day, appear to cross the observer's *meridian* (an imaginary line drawn between the celestial poles through a point immediately above the observer's head). At this instant of time it will lie due north, due south, or immediately overhead. This instant is known as the time of *transit* of the star. If we have an accurate clock and start to measure the time until the next transit of the same star, we find that the time between each transit is 86,164·095 seconds, or 23 hours 56 minutes and 4·095 seconds. If we continue to measure this period we find that it is always the same. We call this *Sidereal Time* because it is measured by the stars. It is used by astronomers and navigators because it has a constant value.

Although the stars are all reliable time-keepers, the Sun and planets of the solar system do not record the passage of time with the same regularity. The Sun in particular is a poor time-keeper. However, it gives light and heat to the Earth and thus controls all life on our planet. We are therefore compelled to use the Sun as the heavenly body by which the length of a day is decided in ordinary human affairs.

If we make the same observations of time with the Sun as we did with the stars we find that the time which elapses between successive transits varies. There are two reasons for this. First, the Earth is moving in its orbit round the Sun, so that, in addition to the daily rotation of the Earth, there is also the forward movement of the Earth in its orbit to be taken into consideration. The effect of the forward motion is to increase the length of the *Apparent Solar Day* to approximately 24 hours because this is the time which elapses before the Sun crosses the observer's meridian again. As we have already seen, the speed with which the Earth moves in its orbit varies according to its position in orbit. This means that the extra time between successive transits owing to the forward motion is a variable quantity of nearly one half-hour.

SIDEREAL TIME AND SOLAR TIME



The difference between Sidereal Time and Solar Time can be seen from this illustration. The yellow lines converge towards the centre of the Sun. The orange lines point to some star which is so far away that these lines can be regarded as parallel. Suppose that we begin to measure the time at the instant labelled 'Position of Earth at first transit' when the star crosses the meridian of the point A on the Earth. Then the period which will elapse before the second transit of the star will be one Sidereal Day of 23 hours 56 minutes 4·095 seconds. If, on the other hand, we begin to measure time when the Sun crosses the meridian of A, the Earth will not have completed one rotation about its axis at the end of one Sidereal Day (the position labelled 'Position of Earth at second transit of star'). In order to complete the Apparent Solar Day, the Earth must continue to rotate until it has passed through the angle marked in white, when the Sun crosses the meridian through the point A. The actual distance along the orbit between the successive positions of the Earth depends upon its velocity, and we have seen that this depends upon the distance between the Sun and Earth.

Because of the difficulties which are thus introduced, astronomers and navigators have introduced two imaginary 'suns' which behave in different ways.

The first of these suns is called the *Mean Sun*, which is an imaginary body moving round the celestial equator at a uniform speed. This is where the Sun would appear to occur throughout the year if the Earth's own axis of rotation were truly perpendicular to the plane of its orbit round the Sun (see page 1967). The time required to complete one Mean Solar Day is divided into 24 hours exactly.

The second of these imaginary bodies is called the *Dynamical Mean Sun*, and this is moving round the Ecliptic at a uniform speed. The time required for one apparent revolution of the Dynamical Mean Sun is the same as that of an Apparent Solar Day, and this, as we have seen, depends upon the distance between the Sun and the Earth, varying with the time of year.

The imaginary movements of the Mean Sun and Dynamical Mean Sun may be related mathematically to give the *Equation of Time*.

From the point of view of everyday life it is clearly inconvenient to have days of variable length. For this reason we make use of the Mean Solar Day which has a constant length of 24 hours. Astronomers measure the solar day from noon, but it would obviously be inconvenient to change the date in the middle of daylight hours. It has become conventional, therefore, to use a Civil Day which has the same length as a Mean Solar Day, but which starts and ends at midnight.

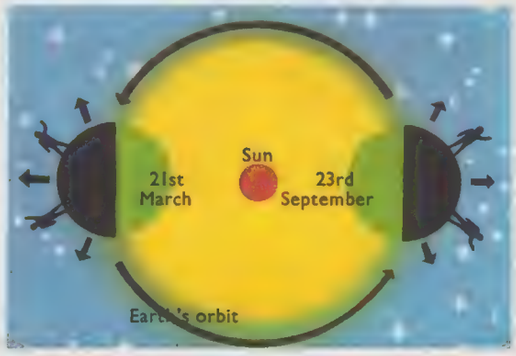
Why people in one hemisphere can always see certain stars

The changes in visible stars

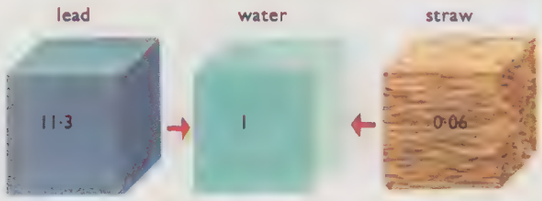
The stars which do not belong to the solar system appear to have fixed relative positions, hence their name 'fixed stars'. The patterns which they make form the constellations, and these constellations appear and disappear at different times of the year. The changes which occur result from the movement of the Earth in its orbit round the Sun. We must, however, distinguish three different parts of the sky. If we are in the northern hemisphere, as shown above, there is one sector of the sky which is visible at all seasons of the year. This is the part to the north, lying around the celestial pole, where the Pole Star (Polaris) is found. There is also an area above the southern hemisphere whose stars we cannot see. This is why we can never see the Southern Cross in Great Britain.

Between these two zones there is part of the celestial sphere which changes with the seasons. The reason for this is explained by the movement of the Earth in its orbit round the Sun. In the illustration, the part of the Earth which faces the Sun is in daylight and the stars are invisible. It is only from that part of the Earth which, as it were, faces outer space that the constellations of fixed stars are visible. As the Earth moves in its orbit, so the outward-facing part faces a different part of the heavens. In the course of the year, therefore, different parts of the sky will become visible during the hours of darkness. The constellations which change with the seasons are those which lie in the southern sky (for an observer in the northern hemisphere) or those in the northern sky (for an observer in the southern hemisphere). A typical example is the constellation of Orion, which in Britain we see during the winter months only. Those towards the celestial pole are always visible, although their positions in the sky will vary from season to season if we always look at the night sky at about the same time.

How the Earth's orbit affects our view of the stars



SPECIFIC GRAVITY



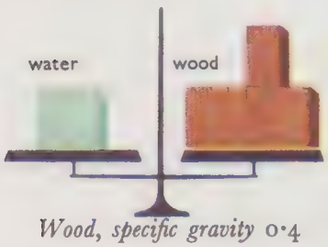
The specific gravity of a substance is the ratio of the weight of a given volume of that substance to the weight of the same volume of water at 4°C

WE all know the old riddle: 'Which is the heavier, a pound of lead or a pound of feathers?' Both of course weigh the same: one pound. Yet a pound of lead would go into a match-box, while a pound of feathers would fill a small cushion. Loosely, we speak of feathers as being lighter than lead, but what we should say is that feathers are *less dense* than lead, since what we really mean is that a *given volume* of lead is heavier than the *same volume* of feathers.

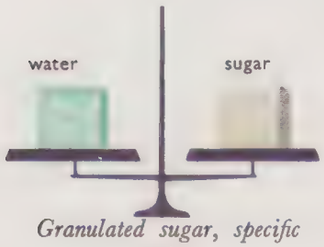
The specific gravity, or *relative density*, of a substance is a figure which tells us how many times lighter or heavier a given volume of that substance is than the same volume of a standard substance, water. Because the specific gravity of water varies as its temperature is raised or lowered, it is necessary to specify the temperature of the water being used as standard, and 4°C is chosen as the temperature at which the specific gravity of water is unity.

At 4°C one litre of water weighs exactly one kilogram. One litre of mercury at 15°C weighs 13·558 kg, and the specific gravity of mercury at 15°C is therefore 13·558. For most practical purposes the variation of the specific gravity of solids and liquids with temperature can be disregarded.

The specific gravity of gases is often related to that of air. Taking water as 1, air, at 0°C and 760 millimetres pressure, has a specific gravity of 0·00129.



Wood, specific gravity 0·4



Granulated sugar, specific gravity 1

Iron, specific gravity 7·8

TABLE OF SPECIFIC GRAVITIES

METALS	
Aluminium	2·7
Antimony	6·6
Arsenic (metallic)	5·73
Barium	3·7
Bismuth	9·8
Cadmium	8·6
Caesium	1·9
Calcium	1·5
Chromium	6·9
Cobalt	8·7
Copper	8·9
Gallium	5·9
Germanium	5·5
Gold	19·3
Indium	7·3
Iridium	22·4
Iron	7·8
Lead	11·3
Lithium	0·53
Magnesium	1·75
Manganese	7·4
Mercury	13·6
Molybdenum	9·0
Nickel	8·9
Osmium	22·5
Palladium	12·2
Platinum	21·4
Potassium	0·87
Rhodium	12·44
Rubidium	1·53
Ruthenium	12·1
Silver	10·5
Sodium	0·97
Strontium	2·5
Tantalum	16·6
Tellurium	6·0
Thallium	11·9
Thorium	11·5
Tin	7·3
Titanium	4·5
Tungsten	19·0
Uranium	18·7
Vanadium	6·0
Zinc	7·1
Zirconium	6·4

It should be noted that the specific gravity of metals may vary according to the method by which they are made. The above figures are average ones.

NON-METALLIC ELEMENTS	
Boron	2·5
Bromine	3·12
Carbon (graphite)	2·25
Carbon (diamond)	3·52
Iodine	4·94
Phosphorus (white)	1·83
Phosphorus (red)	2·2
Selenium	4·5
Silicon	2·42
Sulphur	2·0

GASES (Air=1)	
Acetylene	0·91
Ammonia	0·6
Argon	1·38
Carbon dioxide	1·53
Carbon monoxide	0·97
Chlorine	2·49
Fluorine	1·31
Helium	0·138
Hydrogen	0·069
Krypton	2·87
Methane	0·55
Neon	0·696
Nitric oxide	1·04
Nitrogen	0·97
Nitrous oxide	1·53
Oxygen	1·105
Ozone	1·66
Radon	7·53
Sulphur dioxide	2·26
Xenon	4·52

VARIOUS LIQUIDS (Water=1)	
Acetone	0·79
Alcohol	0·79
Benzene	0·81
Carbon tetrachloride	1·59
Chloroform	1·49
Ether	0·74
Kerosene	0·82
Milk	1·028–1·035
Oil (vegetable)	0·9–0·95
Petrol	0·66–0·7
Turpentine	0·87

VARIOUS SOLIDS	
Amber	1·06–1·11
Asbestos	2·0–2·8
Bone	1·7–2·0
Brick	1·4–2·2
Cardboard	0·7
Celluloid	1·4
Cement	2·7–3·0
Chalk	1·9–2·8
Clay	1·8–2·6
Coal	1·2–1·5
Coke	1·0–1·7
Cork	0·22–0·26
Flint	2·6
Glass (soda)	2·4–2·8
Glass (flint)	2·9–5·9
Granite	2·7
Ivory	1·83–1·92
Leather	0·8–0·9
Limestone	2·68–2·76
Marble	2·6–2·84
Porcelain	2·3–2·5
Quartz	2·65
Rock salt	2·18
Rubber	0·91–1·19
Sandstone	2·14–2·36
Slate	2·6–3·3
Tar	1·02

WOODS	
Ash	0·65–0·85
Balsa	0·11–0·14
Beech	0·7–0·9
Birch	0·51–0·77
Cedar	0·49–0·57
Ebony	1·11–1·33
Elm	0·54–0·6
Lignum vitae	1·17–1·33
Mahogany	0·66–0·85
Oak	0·6–0·9
Willow	0·4–0·6

POLYMERS	
Phenol-formaldehyde (Bakelite)	1·2–1·7
Polyethylene (Alkathene)	0·9–0·93
Polymethacrylate (Perspex)	1·16–1·2
Polystyrene	1·05–1·07
P V C	1·2–1·7

HOW TO FIND A SUBSTANCE'S SPECIFIC GRAVITY

To find the specific gravity of a substance, divide its weight by its volume. If the weight is measured in kilograms the volume must be measured in litres; if the weight is in grams the volume must be measured in millilitres.

In the same way, if we know the volume of a substance, and its specific gravity, we can find its weight by multiplying the two known figures.

CRECY AND AGINCOURT

The battle of Crécy, 1346; the flight of the French from the English archers

EVERYONE has heard of the battles of Crécy and Agincourt, which gave the English two great victories over the French in the Hundred Years War. They were crushing victories, and made two English kings, Edward III and Henry V, famous throughout Europe. French losses were heavy in both battles, and their splendid cavalry was shattered by English archers with their long-bows. These battles were won more as a result of poor French tactics, however, than good English generalship, and neither brought any real gain to England. They served only to prolong a dreary struggle, in which the aggressive ambitions of the English kings brought misery and desolation to much of France, and bankruptcy and civil war to the English Government. The glory of August 1346 and October 1415 was bought at a high price.

Beginning of the Hundred Years War

The English kings could not forget that Henry II, through inheritance and marriage, had ruled over half of France – most of the west from the Pyrenees to Normandy. Much of this was lost during King John's reign, but the south-west portion of it – part of the old duchy of Aquitaine – was left to the English. It was left, however, on the condition agreed at the Treaty of Paris in 1259, that the English king should only hold Aquitaine as the *vassal* of the king of France. This meant that the king of France could continually interfere in the duchy – and he did. But in the 14th century there was a very complicated dispute over the succession to the French throne, and it was possible to claim that the king of England was also the rightful claimant to the crown of France. It was not a very good claim, but it was a useful counter to French interference in Aquitaine. And it was this delicate situation which was the chief cause of the Hundred Years War.

The war began in 1337, when Edward III had been on the throne of England ten years. It began with a flourish rather than with a big battle. Edward collected some allies in Flanders and Germany and had a jewel-studded crown of France made for himself, which he intended to wear in Paris. It was not long, however, before his allies had melted away and the crown had been pawned to pay for his armies. This was not a very auspicious beginning. In 1340 the English won a naval victory at Sluys, but after three years of war Edward had little to show except large debts.

The battle of Crécy

In 1345 things improved for Edward III. An English army operating from Aquitaine began to make some progress, and in July 1346 Edward himself landed with another army in Normandy. His aim was to join with some Flemings farther north and to try to secure a port in France from which his army could be supplied. Calais was the obvious choice.

From his landing place Edward pressed quickly forward to cross the river Seine. A few days after that he crossed the river Somme at a ford below Abbeville and encamped at Crécy, where the French army found him. It seemed to the French as though an easy victory was at hand, for the English army had dwindled from its original 20,000, and was anything but fresh. But from the beginning everything

Effigy of Edward III in Westminster Abbey

went wrong for the French. This is how the chronicler Froissart describes the battle: 'At the same time there fell a great rain, with terrible thunder, and before the rain came flying over both armies a great number of crows, for fear of the approaching tempest. Then presently the air began to clear up, and the sun to shine bright, which was directly in the Frenchmen's eyes, and on the backs of the English. When the Genoese [crossbowmen fighting for the French] had assembled and began to advance, they made a great leap and cry to affright the English, but they stood firm for all that: then the Genoese made another leap, and a fierce cry, and stepped forward a little, and the Englishmen retreated not a foot: thirdly, again they leaped and cried, and marched forward till they came within shot: then they shot fiercely with their crossbows; when the English archers stepped forward one pace, and let fly their arrows so regularly, and so thick, that it appeared like snow.' In face of this the Genoese retreated, and when the French king saw it, he commanded his men to ride over them and slay them where they fled. So the English had a still easier target, and when the French cavalry charged impatiently they were met by the same deadly hail of arrows. The defeat turned into a rout, 4,000 of the French army being left dead on the field. So the way was clear to Calais.

The tomb of the Black Prince at Canterbury Cathedral

The longbow archers of England, who played a vital part in defeating the French at Crécy and Agincourt

The aftermath

The taking of Calais proved difficult, and Edward had to besiege it for a year; but when it fell the inhabitants were driven out and the port peopled by English colonists. For 200 years Calais was an English city.

Ten years after Crécy Edward's son, the Black Prince, inflicted another great defeat on the French at Poitiers, and in 1360 the exhausted combatants made a peace at Brétigny which secured for England all her conquests. Edward III's triumph seemed complete. But in the 1360's his health began to fail, as did his son's; and for the rest of the century the French, avoiding pitched battles and relying for the most part on guerrilla warfare, ate away at the English possessions. While kings and nobles squabbled at home the whole English position in France began to crumble.

The prelude to Agincourt

In 1399 Edward's grandson, King Richard II, was deposed by his cousin Henry Bolingbroke, Duke of Lancaster. Richard II was intelligent and ruthless, but he hated war and had seen little point in reopening the struggle in France. To many of his barons, for whom the French wars could be extremely profitable, this seemed a wretched policy of weakness – and it contributed to Richard's downfall and death.

His successor, Henry Bolingbroke, reigning as Henry IV, intended to make war on France and to go on a Crusade to the Holy Land, but he was in fact too busy dealing with his enemies at home to do either. So it was left to his son Henry of Monmouth, King Henry V, to launch the next attack on France.

To do Henry V justice, he thought he was really asserting his rights. To us he may seem like a pitiless aggressor, but for him it was a sacred duty to win back the ancient rights of the English kings. And war would bring a further advantage in that it would be popular among those very English nobles who might otherwise turn to making war on their own king. Henry was never allowed to forget that his father had ruled by means of a crime. Richard II was much more popular as a royal martyr than he had ever been living. It seemed that only by great feats of arms abroad could Henry V make the throne safe for the Lancastrian line, and he had the great advantage of being a brilliant soldier.

The battle of Agincourt

Henry decided to attack through Normandy, from which his ancestor William I had set out to conquer England. His army was the best equipped ever to set out from English shores. There were siege towers, scaling ladders, pontoon bridges,

artillery, timber for ship repairs, apart from the usual mass of animal fodder, food, arrows, bowstaves, chaplains, chapel choirs, heralds, and players of assorted musical instruments; and on 11th August 1415 the great array landed at the mouth of the Seine.

Very wisely, the French began by leaving this army alone. The mere taking of a suitable supply base – Harfleur – took it a month, and by the end of this siege the summer was so advanced that Henry decided he could do no more than move up to Calais and spend the winter there. It was a long march, and the French shadowed the invaders all the way, gloating as they saw them tiring, failing from disease, a mere shadow of the splendid force which had camped before Harfleur. When this army was about 30 miles south of Calais, the French decided that the moment had come to attack. The small, exhausted English force could surely be brushed aside in one glorious day, and Crécy be revenged.

And so it might have been. But the French committed the very same mistakes they had made at Crécy. Their first heavy, cumbersome cavalry charge was mown down by the English longbow-men. A second, stronger attack by dismounted knights met the same fate. The longbow was not a particularly accurate weapon. It relied for its effect on a closely packed target and on its speed of fire, and the French obliged both by attacking in very close order and attacking slowly. At the end of the day the French had lost 7,000 men, the English – 500. Well could the triumphant Henry ride in full pageantry through the streets of London to sing a *Te Deum* at Westminster Abbey. This surely was a victory for God and for the right.

The English standard, with the lions of England and the fleur-de-lys of France, flutters over the battle; the fleur-de-lys symbolises the English claim to the French throne

The end of the long struggle

Henry V did not live long enough, however, to see that God was essentially neutral. He returned to France the year after Agincourt and found that his very reputation was enough to take the fight out of his enemies. At Troyes in 1420 he signed a treaty which gave him half France and the promise that his son would inherit the whole. But in 1422, at the château of Vincennes, he died, leaving as his heir a nine-month-old boy. The battered French found a new saviour in Joan of Arc, and, though the English captains fought hard to retain what had been won, by 1453 all that was left of the English possessions in France was the fortress of Calais.

The battle of Agincourt, 1415; the final rout of the French (on the right)

SIR THOMAS MORE

SIR THOMAS MORE was born in the City of London on 6th February 1478, the son of a prosperous city merchant. When he left school, young Thomas went to be a page in the household of the Archbishop of Canterbury, Morton; from the Morton household he went to Oxford University, and from Oxford to the Inns of Court in London to study Law. This was an upbringing typical of the day, and it brought Thomas into contact with a circle of brilliant men who were to be famous throughout northern Europe. These men came to be called the Oxford Reformers, and they included John Colet, the great Dutch scholar Erasmus, and Linacre, one of the founders of the Royal College of Physicians.

The Oxford Reformers and their friends were bringing a new spirit of enquiry and criticism into English life. Unlike most English scholars of the previous age, they knew Greek, and they used their knowledge to read the New Testament in the original. Such reading led them to think deeply about the state of the Church of their day, full as it was of laziness, superstition, and corruption. These were days before Luther's great rebellion had burst on the world, before the Protestant Reformation which made men declare for or against the power of the Pope. More, in common with Luther and Erasmus, sought to reform the abuses of the Church and criticised the Pope for his lack of interest in reform, but he was never driven to the extreme anti-papal position of Luther.

There were plenty of conservative churchmen in England who were suspicious of the young man's ideas. But it was difficult not to like him. 'He seems,' wrote Erasmus, 'to be born and made for friendship . . . so pleased with a joke, that it might seem jesting was the main object of his life.' He loved to write farces and to act in them, and, when he married, his home in Chelsea (then a village outside London) was a place to which people loved to go.

More in Parliament

In 1504 More became a Member of Parliament, and by the brilliance of his speeches he soon came to be regarded as one of the leaders of the House of Commons. As such he did not please the grasping old king, Henry VII, and he was sometimes in danger of being thrown into prison for opposing in the Commons the king's excessive demands for money. So he must have been glad when in 1509 the old king died and his son, Henry VIII, came to the throne. More soon became a friend of the young king. In 1523 he became Speaker of the House of Commons, and in 1529, on the fall of Cardinal Wolsey (see page 702), he became Lord Chancellor, the highest office in the realm.

Sir Thomas More and his family
(based on a painting by an artist of the time)

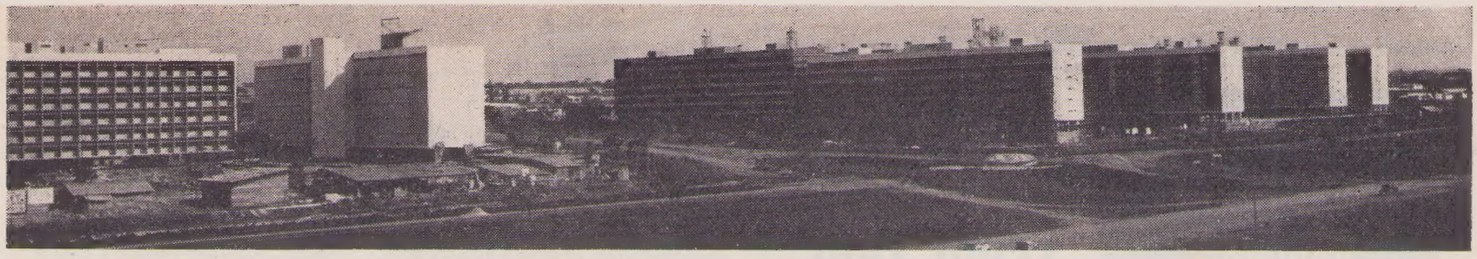
Portrait of Sir Thomas More, after Holbein

A traitor to his king

On the death of his elder brother, Prince Arthur, Henry had married his brother's wife, Catherine of Aragon. Strictly, it was a marriage forbidden by the laws of the Church, but the Pope of the time was ready to investigate the matter further for the king. Yet the marriage produced no son who lived, and if Henry were to die without an heir, England could be thrown into chaos. For Henry, it was essential that he should marry again. Wolsey had fallen because he had been unable to arrange a divorce, and Henry lost no time in making it clear to More that he was expected to do better.

But whatever More may have thought of the Pope at one time, he was now convinced that no man had the power to transgress the Pope's commands on a matter of Church Law. If the Pope was prepared to give Henry a divorce all was well. If he was not, then Henry must remain married to Catherine. Henry's fury and obstinacy knew no bounds. He was determined to have his divorce, and in Thomas Cranmer he created an archbishop who was ready to arrange it. He rushed it through and married Anne Boleyn, commanded the English clergy in Convocation to submit, and prepared for Parliament an Act which said that he and not the Pope was Supreme Head of the English Church. Still all might have been well for More, but Henry now insisted that all men he chose should take an oath, solemnly stating before God that Henry was Supreme Head of the English Church, and that the Pope had no power over it at all.

Thomas More could not swear such an oath. To refuse the oath was treason against the king; but to swear it was mortal sin, rebellion against God. His choice was clear. He was brought to the block on 6th July 1535. He died as he had lived, with a jest on his lips. Covering his eyes with a cloth, he knelt on the block, asking the executioner one last request – that he should push his beard aside. It did not deserve to suffer, he said, since 'it had never committed any treason'.



FOCUS ON
BRASILIA

THE DREAM THAT BECAME A NIGHTMARE

THREE years ago Brasilia became Brazil's capital. This ultra-modern city was built far away from any centre of population, near to the edge of the Mato Grosso, Brazil's great central plain. Now it has almost stopped growing.

Many Brazilians think that the idea of ever building it at all was a bad one, and that Brasilia has turned into a 600-million-dollar flop.

It was to have been the greatest city the world had ever seen; the realisation of a 100-year-old Brazilian dream. This dream had been to open up the centre of Brazil by giving this underpopulated and underdeveloped area a magnificent new city.

Today the dream of a capital in the heart of Brazil has been realised. The city is certainly impressive, with its broad avenues and futuristic buildings. But it is rapidly turning into something of a ghost city because people from other parts of Brazil do not want to live in it.

The main reason for this is Brasilia's remoteness. It rises out of virgin jungle; most of its roads go nowhere, and unless one wishes to face a 700-mile journey from the coast, the only way in and out of Brasilia is by air.

One of the most ironic things about Brasilia is that it already has its slums. Cheap labour was imported from poverty-stricken north-west Brazil, and the people were housed in shacks while the new capital was being built.

The 'rubbish dump at the bottom of the garden' – the shantytown which has sprung up next to Brazil's new capital.

The plan was for the resultant shantytown to be demolished when Brasilia was completed. But the sprawling collection of shacks has become a second 'city' with some 40,000 inhabitants . . . the rubbish dump at the bottom of the beautiful garden.

Señor Juscelino Kubitschek, former Brazilian President, was the main driving force behind the building of Brasilia. He concentrated on it to the exclusion of practically everything else – and in the process he left Brazil almost bankrupt.

Now the country has the worst inflation it has ever known. There is little money to spare for Brasilia's grand projects, and the city is already showing signs of neglect.

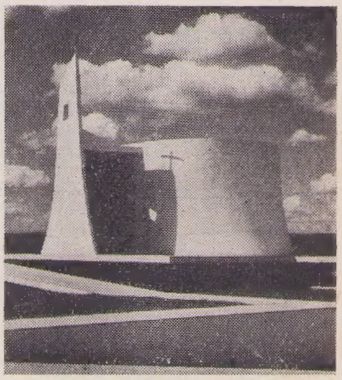
A great proportion of its inhabitants are civil servants, but the more senior among them only work in Brasilia. At the week-ends they fly 'home' to Rio de Janeiro or Sao Paulo – and this adds to the ghost city atmosphere.

Many Brazilians are fully aware that millions of their countrymen still live in shacks and exist on a diet of beans and rice; that two out of three are illiterate; and that even in Rio 700,000 people live in the shantytowns plastered on the hills overlooking elegant Copacabana beach. With this at the back of their minds, they ask: 'What is the point of carrying on with this fabulous new city when there is so much more important work to be done in the country?'

This is the problem that threatens the future of Brasilia.

The fabulous Copacabana beach in Brazil's largest city, Rio de Janeiro. Many civil servants who work in Brasilia fly back to Rio for the weekend. Rising above the beach is one of the hills where Rio's poorer people live.

A model of Brasilia's projected cathedral.



An unusually designed chapel attached to the President's Palace.

The Queen is Head of the Church of England; being Queen of Scotland, she is also head of the Scottish Church. But members of the Church of England are Protestant Anglicans, and members of the Church of Scotland are Presbyterians; so what is the religion of the Queen? Can she be both Presbyterian and Anglican? This is what a member of the Knowledge *staff tried to find out. With commendable industry he rang the British Museum, Buckingham Palace and the Home Office. None could help. It was left to the Church Information Service to provide the answer: the Queen* officially *changes her religion. In Scotland she is a Presbyterian, in England an Anglican.*

Announcement for readers of YELLOW Knowledge

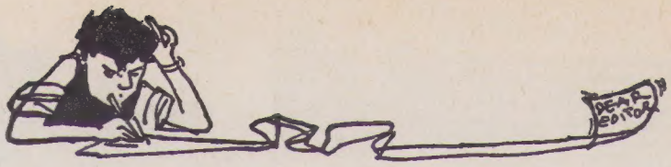
The Standard Binder for Volume 7

The Easibinder for Volumes 7 & 8

AVAILABLE from your NEWSAGENT NOW!

The standard binder for Volume 7 and the Easibinder for Volumes 7 and 8 are available from your newsagent now. The standard binder costs 3s. 6d., and the Easibinder 13s. 6d. In case of difficulty, write direct to Department B, Knowledge, 37 Hertford Street, London W.1. There is a charge of 1s. 3d. on each order from Department B, but if you order more than one binder the charge is still only 1s. 3d.

With this issue you come to the end of Volume 6. In the centre of Knowledge *this week is the title page and table of contents for Volume 7. This goes on the first string of your Volume 7 standard binder or the first rod of your Volumes 7 and 8 Easibinder. Next week's issue contains the index for Volume 6.*



Up the Amazon

DEAR EDITOR—Last year I was given the opportunity to have a holiday of a lifetime, visiting the little mission station of Zaracua; this involved a tremendous journey up the Amazon, through the forests of Brazil and so to the borders of Colombia. On the way I stayed at Belem where the market is held every morning on the quayside with the boats, each with gaily coloured sails, drawn up alongside.

From Belem I went to Santarem, which was founded by some Americans when slavery was abolished in North America, and they did not wish to give up their slaves. Then on to Manaos, with its famous opera house, the cupola of which is blue and yellow glass, visible for miles over the jungle. Here Madame Patti sang on her last world tour.

It was a long journey to Zaracua from Manaos and the heat was tremendous. I saw the tiny huts of the rubber collectors, and I shall never forget the hundreds of butterflies and parrots which surrounded us all the time.

Elizabeth Purcell,
6 Albany Terrace,
Britannia Square, Worcester.

Floral Emblem

DEAR EDITOR—The emblem of Western Australia (where I live) is a flower called 'kangaroo paw'. This beautiful plant was first collected in the Swan River Colony in the early years of its settlement, and described by D. Don in 1836.

Kangaroo paw is a low shrub, with broad, tapering leaves 1–2 feet long. The flowering stem may reach 4 feet in height, and it bears a number of large flowers. The stem is covered with deep red or purple hairs, while the hairs on the flower are green. There are ten species of kangaroo paw, distinguished mainly by colour, but they are found only in Western Australia.

This is one of our many colourful spring flowers, coming into bloom between August and October.

Would other readers who are keen on botany please write and tell me about the wild flowers of their countries?

Merryl Williams (age 14),
Merravis, Toolibin,
Western Australia.

Top Churches

DEAR EDITOR—Most Catholics would probably think that St Peter's is the senior church in the Catholic Church.

This is not so. The senior church is that of St John Lateran. It is an archbasilica, while St Peter's is a plain basilica.

A basilica is a title of honour conferred on a church because of its importance. It was originally an architectural term.

There are seven basilicas in Rome including St Peter's and St John Lateran. Of course, there are basilicas outside Rome: Lourdes is one, but there are none in Britain.

The Pope is both head of the Catholic Church and Bishop of Rome. When acting in his former capacity he uses St Peter's. As Bishop of Rome he uses St John Lateran, an older foundation than St Peter's, and the senior church in the senior Catholic bishopric.

St Peter's Church, in contrast, might be described as the parish church of the Catholic Church, for St Peter's parish comprises 'the whole Catholic world'.

Mary Lambert,
London, W.1.

Very interesting, Mary. There will be an article on St Peter's in Knowledge *129. Have any other readers any interesting facts about churches?—Editor.*

Unexpected Present

DEAR EDITOR—During the last war my husband was driving home to my son's birthday party when he was stopped by the chauffeur of a large car which had broken down. Inside the car was King George VI.

The king asked my husband if he would drive him back to London. My husband agreed. During the journey my husband happened to mention that it was his son's birthday. The king gave my husband half a crown to give him.

When my husband arrived late for the party he was most unpopular – that is, until he produced the birthday present from the king.

M. J. Armstrong,
16 Queen's Gate Place,
London, S.W.7.

Can you answer these?

1. What do you call a person who is a 'lover of books'?
2. What is the difference between fiction and non-fiction?
3. *Twenty-five* is an autobiographical account of the early years of Beverley Nichols. Who wrote it?
4. What is a 'bibliobus'?
5. How was Andrew Carnegie connected with libraries?
6. Where, in accordance with copyright laws, are copies of all books published in the United Kingdom lodged?
7. On what does the burden of the expense of libraries fall – rates (local government) or taxes (central government)?
8. If you wish to consult the *Encyclopædia Britannica*, to which department of the Public Library would you go – the lending department, the reference room, or the reading room?

ANSWERS

1. *A bibliophile.*
2. *Fiction consists of stories, non-fiction of works based on fact.*
3. *Beverley Nichols.*
4. *A name which has been given to a travelling caravan library.*
5. *He gave vast sums of money for the provision of town libraries.*
6. *The British Museum Library. (Other copyright libraries are the Bodleian at Oxford, Cambridge University Library, Scottish National Library, Trinity College, Dublin, and the National Library of Wales.)*
7. *Rates.*
8. *The reference room.*

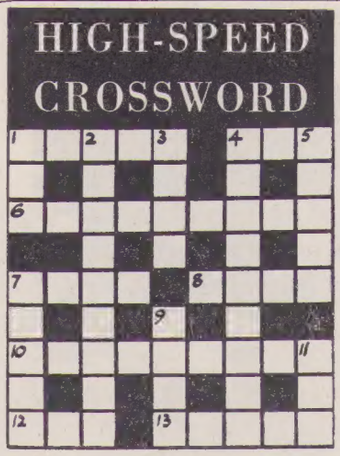
BRAIN ? BOX

1. (a) GET GORSE;
   (b) DID VAST;
   (c) PICK TARTS;
   (d) DRAW NEST.
   You can probably see little sense or connection in the above phrases. When you have worked out their anagrams, however, you will see that these make a logical group. (Look first for the letters they all have in common.)
2. Tom and George are brothers, but not twins. This year the digits of Tom's age are the reverse of the digits of George's age. Furthermore, Tom is just half as old as his Mother this year and George just half as old as his Father. And the digits of Mother's age are the reverse of those of Father's age. How old are they all?
3. It is said that a clock-making firm has been requested to put on the market clocks that 'go backwards' – that is, with the hands moving in an anti-clockwise direction. For supply to what establishments?

ANSWERS

1. (a) St George; (b) St David; (c) St Patrick; (d) St Andrew – the four patron saints of the British Isles. 2. Tom, 34; George, 43; Mother, 68; Father, 86. 3. Hairdressers' – where clients habitually see the clock reflected in the mirror.

HIGH-SPEED CROSSWORD



Clues Across

1. European country for castles, and rain on the plains? (5).
4. Pathetic little cry (3).
6. Gets back (a dog —— the shot bird) (9).
7. Between head and body (4).
8. Boy's name (4).
10. Whitening (9).
12. Road vehicle for public transport (3).
13. Possessed (5).

Clues Down

1. How you address your master (3).
2. Defenders' opponents (9).
3. You have it more or less at your finger-tips (4).
4. Ruler (9).
5. Fundamental (5).
7. Another ruler (India, this time) (5).
9. Sound return (4).
11. 'O ——, our help in ages past' (3).

Solution next week.

SOLUTION TO LAST WEEK'S CROSSWORD

ACROSS: 1, Eatable; 6, Tears; 8, Ashy; 9, Beef; 10, Area; 12, Sore; 13, Essay; 14, Oranges.

DOWN: 2, They; 3, Barb; 4, Granada; 5, Fifteen; 6, Three; 7, Sepoy; 11, Asia; 12, Sang.

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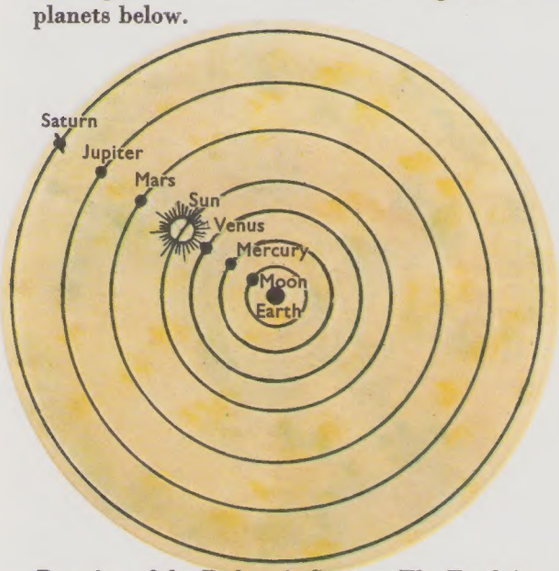
it. In the 2nd century B C this belief was laid down by Ptolemy in his famous system.

Ptolemy (Claudius Ptolemaeus, of Alexandria) demonstrated his *hypothesis* (supposition made as basis for reasoning) with numbers. He gave measurements for the planets then known. His system was held to be better and more exact than any previous ones, and stood unchallenged for centuries.

In 1543 the astronomer Nicolaus Copernicus published a book stating that Ptolemy's theory was false: the centre of the Universe is the Sun, said Copernicus, and round it the Earth, the Moon, and five other planets move in circles. High above is the sphere of the fixed stars, which is a motionless sphere embracing the Universe and influencing all the planets below.

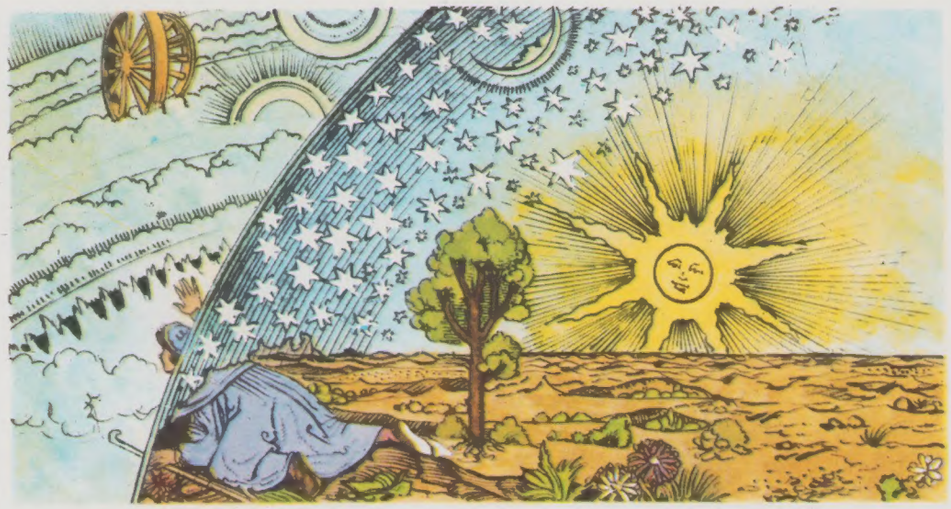


Drawing of the Ptolemaic System. The Earth is at the centre of the Universe, and the planets revolve round it

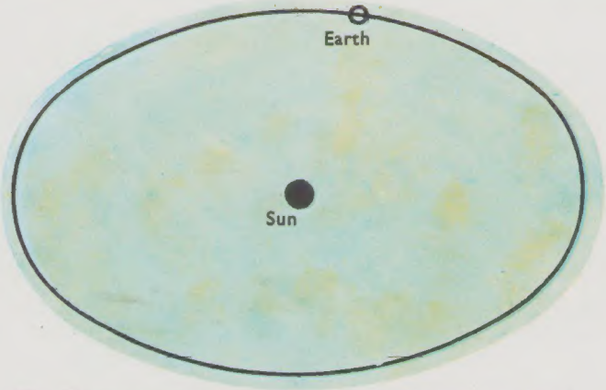
In the two centuries following, astronomy advanced greatly, through the work of Johann Kepler (1571–1630), Galileo Galilei (1564–1642), and Sir Isaac Newton (1642–1727).

Galileo was the first to use a telescope to observe the stars, and he discovered that the Sun rotates on its own axis like the Earth. He also laid down a law which later inspired Newton's great imaginative discovery – that a body goes on moving until some outside cause interferes, either changing the motion or stopping it.

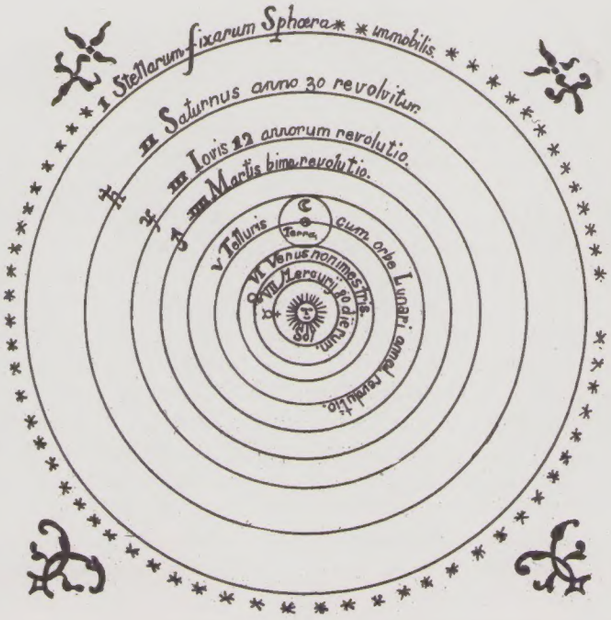
Since the planets move round the Sun as though they were tied by an invisible cord, they cannot go on in a straight line. What ties them to the Sun, as Newton discovered, is



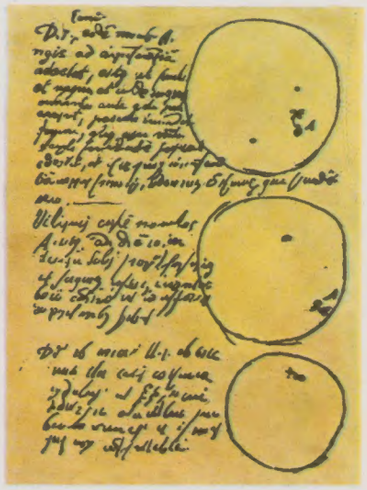
How the world works – according to an ingenious mediaeval picture. A traveller who has reached the edge of the Earth sees beyond the sky the complicated mechanism of wheels and circles which make the stars move (from Flammarion's Astronomy)



The German astronomer Johann Kepler (1571–1630) *discovered that the planets move round the Sun on elliptical, and not circular, orbits*



The Copernican System (facsimile of the diagram published in Copernicus's book, 1543)



Facsimile of drawings of sun spots, made by Galileo

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Hippocrates *1970*
The discovery of metals *1972*
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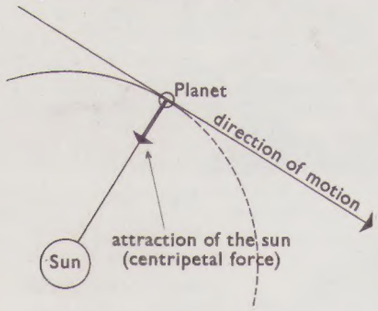
the force of attraction which exists between any two bodies.

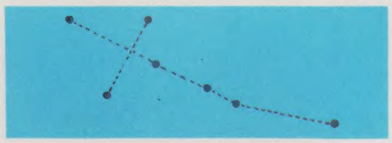
The 18th century and after

The 18th century saw another old view disproved: that there was a motionless crystal sphere surrounding the solar

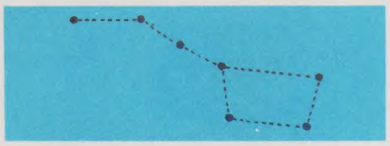


The centripetal force keeps the planet in its orbit. Without this force the planet would fly off at a tangent

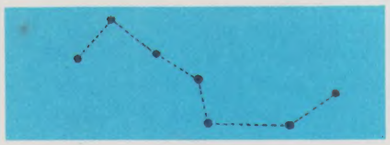
system. Edmund Halley in 1718, and Tobias Mayer in about 1755, showed that many so-called 'fixed' stars were in fact moving. They were really



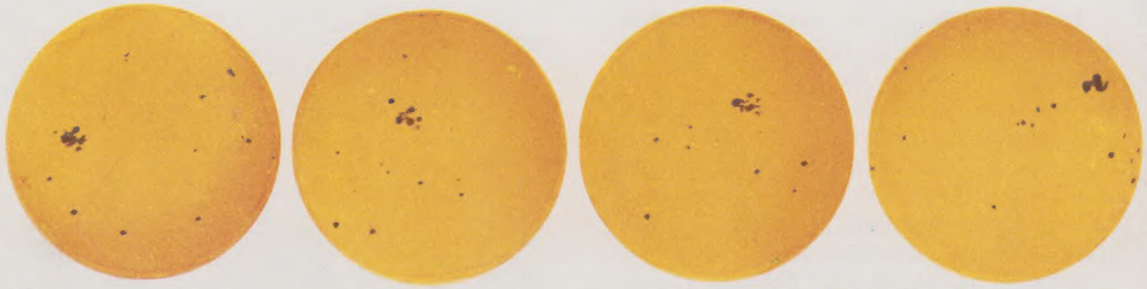
The Great Bear 50,000 years ago



The Great Bear today



The Great Bear in 50,000 years' time



Four pictures of the Sun, from photographs taken at intervals of two days. Notice how the sun spots, in their changing positions, prove that the Sun revolves from left to right

suns, similar to our own.

Within a few decades, with the aid of ever more powerful telescopes, millions and then thousands of millions of suns were discovered. The suns nearest our Earth turned out to be at vast distances hardly to be imagined by the human mind. The unit for measuring distance is the light-year (5·88 million million miles, the distance light travels in one year; in one second light travels 186,000 miles).

The sun nearest to us (the star Proxima Centauri) is about four light-years away. With bigger and better telescopes, we can probe much farther than that. Today we can see stars up to *five thousand million* light-years away.

What is the Universe? How big is it? What is it made of? These are all questions that have been answered in various different ways, and no doubt new answers will be given in the future, to be superseded in their turn. Newton's laws themselves have already been partly outmoded because of the discoveries of Einstein.

This is the way of science: continual research and improvement, and the overcoming of doubts before new conclusions are reached. We are constantly learning more about the known world and the extent of the unknown.

SCIENCE BECOMES MORE DIFFICULT

Our ancestor, amazed at so much progress, might rashly think that we knew everything about the world around us. But today we are in many ways more doubtful about it than before. In the late 19th century, for instance, men thought that physics had solved all the main problems, and that all we had to do was to perfect our means of measurement and everything would become known. At that time it was thought that the atom was a definite object, hard and impenetrable. The very word means 'uncuttable'.

Today we know that the atom has a very complex structure of very small dimensions. Round the nucleus of an atom, two-tenths of a thousandth of a millionth of a millimetre away (an immense distance in proportion to the dimensions of the nucleus), revolve one or more electrons at a speed of 31,250 miles a second (a sixth of the speed of light). Each electron thus completes in one second a number of orbits represented by the figure 1 followed by 15 noughts.

Thus we cannot say exactly where an electron is at any given time, much less see it. Physics can at best study and predict the behaviour of large groups of atoms and electrons, not that of a single atom or electron. This restriction is already regarded as a law and is called the 'principle of uncertainty'.

As scientific research probes deeper and deeper, it becomes more and more difficult to describe the new discoveries in simple and easily understood terms. Complicated mathematical formulae and equations are now common in every field of science.

From science, technology has gathered remarkable methods for increasing the comfort and length of human life. Science has explained many natural phenomena, and will go on doing so. But the more we learn, the more new questions present themselves, leading scientists ever further in their search for knowledge of our Universe.

$$
\left.\begin{array}{l}
\frac{21}{4} m + \frac{1233}{32} m^3 + \frac{15165}{64} m^5 + \frac{2844993}{2048} m^6 \\
+ \frac{307187071}{36864} m^7 + \frac{91720676239}{1769472} m^8 \\
+ \frac{51}{32} m e^2 + \frac{189}{32} m e'^2 - \frac{63}{8} m \gamma^2
\end{array}\right\} e e' \operatorname{sen}(\varphi - \varphi')
$$

$$
\left.\begin{array}{l}
-\frac{21}{4} m - \frac{717}{32} m^2 - \frac{3215}{32} m^3 - \frac{2806183}{6144} m^6 \\
+ \frac{19962409}{2216} m^5 - \frac{18084760319}{1760472} m^6 \\
- \frac{51}{52} m e^2 - \frac{189}{32} m e'^2 + \frac{63}{8} m \gamma^2
\end{array}\right\} e e' \operatorname{sen}(\psi + \varphi')
$$

This is a small part of the final formula worked out by the French mathematician Pontécoulant to prove his theory of the orbit of the Moon. In order to give the formula in full, it would be necessary to fill 23 pages of an ordinary book with algebraical signs